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Review of selected research activities for the period 1 January 1987 - December 1987

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INTRODUCTION

The year 1987 was one of consolidation. Many long-term projects are just now beginning to yield the kind of information we need in order to develop practical tools for forest management in Ontario. Just one example: for the first time, our biotechnologists working with tissue culture have been able to encourage embryonic shoots to root successfully. Eventually, we hope to see this technique refined to permit the rooting of adventitious shoots, which would be a powerful addition to current cloning techniques.

Many years of work on electrical impedance measurement have advanced our knowledge to the point that the technique is now used routinely in nursery operations. In 1987, impedance measurements were used to pinpoint the best fall lifting times for stock at Swastika, Midhurst, Orono, Kemptville, Thunder Bay, Dryden and Gogoma, as well as at Pineland Tree Nursery in Manitoba.

For more than a year now, OTIFBI scientists have been knee-deep in blueprints, plans and equipment lists for our new forestry research facility which is now being constructed in Sault Ste. Marie. Staff are enthusiastically anticipating occupying the new headquarters, laboratories, greenhouses and arboreta in the summer of 1990, when OTIFBI staff are scheduled to join the rest of Forest Resources Group in "the Soo." Over the short term, the move may be somewhat disruptive, but to put things into perspective, it will of course be "business as usual" in OTIFBI's most important laboratory: the living laboratory of Ontario's forest lands.

In conjunction with the Great Lakes Forestry Centre, OTIFBI will be hosting a Forestry Research Marketplace to be held in Toronto in November 1989. Focusing on Ontario's forests, this will probably be the largest forest research exhibit ever held in Canada. Some 200 research scientists will come together for two days to share the results of their forest research with forest managers, forestry practitioners, students and the general public. The research scientists and I would be delighted to welcome you there to discuss the future of Ontario's forests.

D.P. Drysdale
General Manager
OTIFBI

TREE IMPROVEMENT

Physiological Genetics

Variation in Red Pine Full-Sibs

Eleven full-sib families were generated to investigate inheritance of extreme branching habit in red pine (*Pinus resinosa*). After two years in nursery beds, and prior to establishment in test plantations, patterns of branching were not yet apparent in the families. However, mean family heights were quite variable after two years' growth. Families derived from Maritimes clones (Nova Scotia and New Brunswick) were up to 80% taller than families of boreal Ontario (Hearst) x Maritimes parents. These growth differences reflect the adaptive differences between the respective populations from which the parents were sampled, since boreal environments are generally more vigorous than Maritime environments, and growth processes tend to be highly attuned to environmental cues for optimum fitness.

(G. Buchert and T. Taylor)

Hard Pine Trial

At the request of Napanee District, a comparative planting of several different species and hybrids of hard pines was established in 1987. Quarter-acre blocks with 900 trees per block were established on a sandy loam site in Eastern Ontario. Seed sources included were: Scotch pine (*P. sylvestris*) from Latvia and the Ukraine; Austrian pine (*P. nigra*); Austrian x Japanese red pine (*P. densiflora*) from Michigan State University; pitch pine (*P. rigida*) x loblolly pine (*P. taeda*) sources from the U.S. Forest Service and from Ontario collections; and red pine from an Ontario seed orchard. Growth, survival and form will be assessed periodically.

(G. Buchert, T. Taylor and D. Higgs)

Pitch Pine Populations

Fifth-year growth and survival data from a series of seven pitch pine genetic tests established across southern Ontario show early indications of above-average growth from Lake Champlain sources. The sources from Vermont and New York shores of Lake Champlain are consistently ranked the tallest among more than 160 open-pollinated families from Ontario, Quebec, New York, Pennsylvania and New England, regardless of soil type or local climate at the test site. These tests are part of a population study to identify sources of well-adapted pitch pine for possible future hybridization with loblolly pine.

(G. Buchert, T. Taylor and D. Higgs)

Comparison of Spring-Sown and Overwintered Jack Pine Leach Tube Container Stock

A container study was initiated for jack pine (*P. banksiana*) grown in Ray Leach Supercell tubes at OTIFBI. Field observations on population studies established in Blind River and Chapleau Districts in 1984 indicated that the Leach tube stock produced at OTIFBI was particularly weak-stemmed. Much of

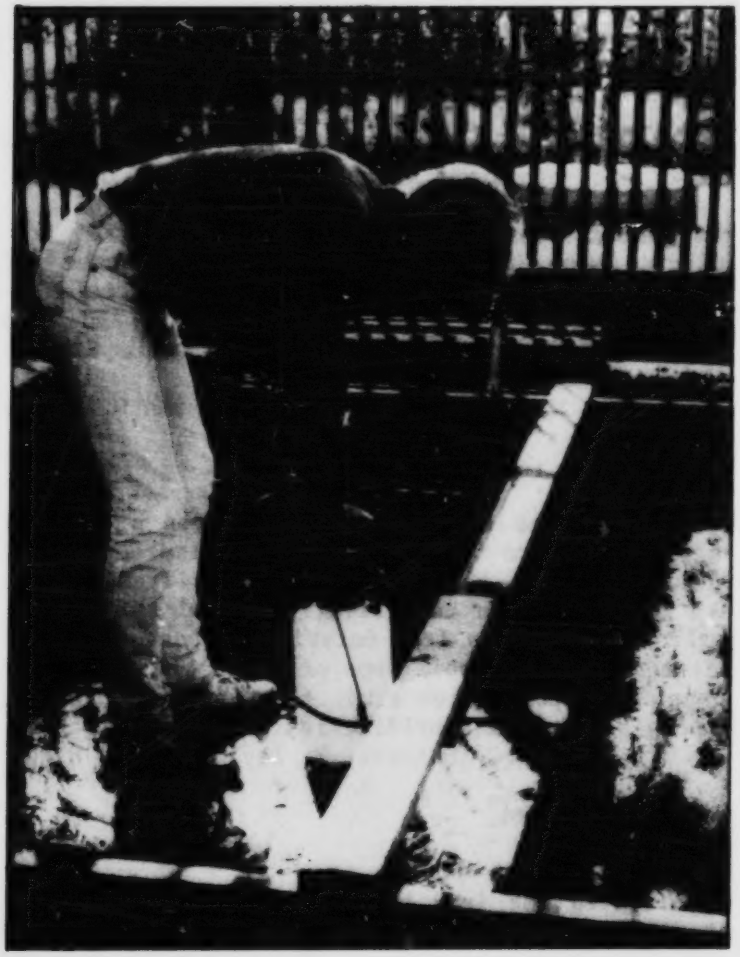
the overwintered stock trailed along the ground in its first year. The container study was designed to examine soil mix, tube spacing, fertilizer concentration and photoperiod on overwintered and spring-sown Leach tube jack pine and the effect of these factors on stem strength. Tree morphology studies will be conducted on sample trees to determine various shoot/root factors. The experiment will be outplanted at Chapleau District for growth observations over a five-year period.

(T. Taylor, G. Buchert, D. Higgs, K. Fischer and L. Farintosh)

Growth Study in White Spruce

Periodic shoot growth was measured on 19 white spruce (*Picea glauca*) full-sib families for the third consecutive growing season. Measurements were made three times weekly from before bud flush until shoot elongation ceased. Comparisons will be made between and within families for total growth, period of maximum growth and average growth rate. Variation between years will be examined along with climatic effects.

(G. Buchert, L. Farintosh and K. Fischer)



Resource technician Russ Booker is spraying hybrid white pine with basidiospores (blister rust) to test the rust resistance of the different crosses.

Cone Induction

The hope of manipulating pollen- and seed-cone production at will has been the dream of forest tree breeders. When cone crops are desired for breeding to produce seed for progeny testing or for reforestation, trees will be treated to turn on the genes controlling the expression for the production of pollen and seed cones. When the demand for cone crops is not imminent, trees will be tended for vegetative production to increase cone production area.

Black spruce (*Picea mariana*) appears to be very responsive to the spraying of gibberellic acid 4/7 ($GA_{4/7}$) onto the foliage to influence bud differentiation for seed-cone production. Other treatments such as heat, root pruning, high humidity, and a combination of any two treatments are effective in promoting pollen and seed cones. Although the latter were not as effective as $GA_{4/7}$ in promoting seed cones, a combination of heat and high humidity significantly enhanced pollen cone production.

Black spruce trees in a seed orchard and in containers were used for the studies. The objectives were: i) to evaluate the effectiveness of $GA_{4/7}$ spraying in consecutive years; ii) to establish the optimal concentration of $GA_{4/7}$ for bud differentiation by foliage spraying in potted trees; and iii) to investigate the effect of a combination of $GA_{4/7}$ and heat treatment, root pruning and heat treatment, and heat and high-humidity treatment on the cone production of potted trees.

Foliar Spraying in a Seed Orchard

Eighty trees representing 10 clones growing in Glencairn seed orchard were used. In 1986, foliage of the top three whorls and internodes was sprayed weekly with $GA_{4/7}$; the fourth whorl, which was treated in 1985, was not sprayed. The spraying solution contained 20% ethanol, 0.05% Tween 20 surfactant, and 0, 400, 800 or 1 200 mg/L $GA_{4/7}$. Spraying began one week after lateral vegetative bud burst and continued through the end of lateral shoot elongation for a total of six weeks. Grafts sprayed in 1986 were assessed for cone crops in 1987.

The results of two consecutive years of spraying indicated that grafts could be stimulated to increase seed-cone production significantly. Cones were produced for two years running, though there was a decrease in the second year. The responsiveness of black spruce to the treatment will facilitate seed production for breeding studies and nursery stock production. Grafts sprayed with the solution without $GA_{4/7}$ produced an average of 81 cones per graft, while those sprayed with the solution containing 400, 800 and 1 200 mg/L $GA_{4/7}$ produced an average of 197, 176 and 212 cones per graft, respectively. No significant differences were found among the three $GA_{4/7}$ concentrations used. The optimal concentration appeared to be 400 mg/L, which conformed with the 1986 results (Table 1).

TABLE 1 Average number of 1986* and 1987 seed cones per crown (branches including the upper three whorls) sprayed with $GA_{4/7}$ in 1985 and 1986, respectively, in a grafted seed orchard in black spruce.

$GA_{4/7}$ concentration (mg/L)	Average number of seed cones per crown (±SE) in 1986*	1987
0	130.1 ± 18.2	80.5 ± 23.5
400	245.5 ± 27.8	196.5 ± 36.6
800	235.3 ± 26.7	175.8 ± 26.7
1200	282.6 ± 33.4	212.4 ± 36.8

* Can. J. For. Res. 18: 139-142, 1988. (R.H. Ho and O. Hak)

A Combination of $GA_{4/7}$ and Heat Treatment in a Greenhouse

The experiment was a 4x4 factorial design, combining four spraying concentrations (0, 200, 400 and 800 mg/L $GA_{4/7}$) with four spraying periods. Two ramets each of 15 clones of three-year-old grafts growing in 15-litre containers were sprayed weekly with each of the $GA_{4/7}$ solutions for six weeks; each spraying period commenced three weeks into the previous period, for a three-week overlap. Grafts were sprayed beginning about a week after lateral vegetative bud burst. During the period of treatment, the grafts were kept in a greenhouse with a photoperiod of 18 hours and temperatures of 30°C during the day and 20°C at night.

$GA_{4/7}$ spraying was effective in enhancing seed-cone production when the six-week treatment was initiated a week after lateral vegetative bud burst and at least two weeks before termination of the lateral shoot elongation (Table 2). The increase in $GA_{4/7}$ concentration did not induce a significant increase in production. Heat treatment did play a role in promotion of seed cones, as the controls in the first two periods of treatment produced significantly more seed cones than those which were cultured outdoors until they were brought into the greenhouse at the end of shoot elongation.

TABLE 2 Average number of 1987 seed cones per graft (±SE) in potted black spruce trees which were brought into a greenhouse and sprayed weekly with four concentrations of $GA_{4/7}$, one for each week of six weeks, at the different stages of shoot elongation in 1986.

$GA_{4/7}$ concentration mg/L	Spraying periods 5/13-6/24	6/3-7/15	6/25-8/5	7/15-8/26
0	14.5 ± 8.1	9.9 ± 4.8	0.1 ± 0.1	0.1 ± 0.1
200	31.6 ± 8.6	38.1 ± 8.3	0.3 ± 0.1	0.2 ± 0.2
400	41.7 ± 14.9	34.7 ± 5.9	0.5 ± 0.2	0.0 ± 0.0
800	28.2 ± 13.3	22.5 ± 5.2	0.1 ± 0.1	0.3 ± 0.2

The mortality of potted grafts increased with the increasing concentration of $GA_{4/7}$, occurring in the periods when spraying was most effective in promoting seed-cone production (Table 3). Droopy branches were

the first symptom after spraying, followed by some discoloration of needles. Based on mortality and seed-cone production, grafts were best sprayed weekly with 200 mg/L $GA_{4/7}$ beginning two weeks before termination of the rapid period of lateral shoot elongation.

TABLE 3 Percentage of mortality in potted black spruce grafts brought into a greenhouse and sprayed weekly with different concentrations of $GA_{4/7}$ at various stages of shoot elongation in 1986.

$GA_{4/7}$ concentration mg/L	Spraying periods 5/13-6/24	6/3-7/15	6/25-8/5	7/15-8/26
0	6.7	3.3	0	3.3
200	43.3	13.3	6.7	0
400	56.7	20.0	10.0	0
800	60.0	23.3	10.0	6.7

(R.H. Ho and O. Hak)

A Combination of Root Pruning and Heat Treatment in a Greenhouse

One-half of 256 three-year-old grafts (16 ramets per clone, 16 clones) and 160 five-year-old grafts (16 ramets per clone, 10 clones) were root-pruned and repotted in 15-litre pots, and the other half were repotted in the same-sized containers without root pruning. The three-year-old grafts averaged 0.7 m in height and the five-year-old 1.2 m.

Four periods of heat treatment were factored with two root prunings for each age class. Two ramets per clone of each age class were used for each treatment. One set each of grafts with and without root pruning per age class was brought into a greenhouse with an 18-hour photoperiod and temperatures of 30°C during the day and 20°C at night, a week after lateral vegetative bud burst, and kept there for five weeks before being transferred outdoors. The second set was brought in at the same time and kept for nine weeks, while the third set was brought into the greenhouse five weeks after bud burst and kept for five weeks. A control set was kept outdoors throughout the experiment.

Heat treatment for nine weeks significantly increased seed-cone production on five-year-old grafts without root pruning, while root pruning without a combined treatment of heat was effective in promoting seed cones on the same age of grafts (Table 4). Five-year-old grafts without root pruning produced more pollen cones than those with root pruning whether grown indoors or outdoors (Table 5). Either heat treatment, root pruning, or a combination of the two had no effect on seed- and pollen-cone production in three-year-old grafts. Pollen viability in both age classes appeared to be correlated to tree vigour, not to root pruning and/or heat treatment (Table 5). Prolonging heat treatment to five-year-old grafts with root pruning had a detrimental effect, as 35% of the grafts died after nine weeks of growing in the heated greenhouse (Table 6).

TABLE 4 Average number of 1987 seed cones per graft (±SE) in three- and five-year-old black spruce grafts which were repotted without or with root pruning before heat treatment at different stages of shoot elongation.

Treatments	Weeks after bud burst	Average number of seed cones per graft			
		Without root pruning		With root pruning	
		3 yrs. old	5 yrs. old	3 yrs. old	5 yrs. old
Outdoor		1.4 ± 1.2	53.0 ± 19.8[a*]	0.8 ± 0.3	115.9 ± 27.1[b]
Indoor					
5/14-6/18	1	0.2 ± 0.1	74.2 ± 17.5[ab]	1.6 ± 0.8	56.4 ± 11.9[a]
6/11-7/16	5	5.4 ± 4.6	97.7 ± 25.5[ab]	10.2 ± 2.9	59.6 ± 13.5[a]
5/14-7/16	1	0.2 ± 0.3	126.6 ± 23.2[b]	1.3 ± 1.1	68.5 ± 15.7[a]

* means for each age by treatment followed by the same letter do not differ significantly at $p \leq 0.01$ based on the Scheffe's multiple comparison

TABLE 5 Average percentage of pollen germination (±SE) of three- and five-year-old black spruce grafts which were repotted with or without root pruning before heat treatment at different stages of shoot elongation.

Treatments	Grafts without root pruning		Grafts with root pruning	
	3 yrs. old	5 yrs. old	3 yrs. old	5 yrs. old
	% of grafts producing pollen			
Outdoor	15	100	13	41
Indoor				
5/14 - 6/18	13	85	10	78
6/11 - 7/16	22	95	38	75
5/14 - 7/16	7	90	17	77
	Pollen germination			
Outdoor	67.4 ± 11.1	80.3 ± 2.7	50.5 ± 15.3	71.3 ± 2.4
Indoor				
5/14 - 6/18	60.5 ± 13.6	70.8 ± 3.7	33.7 ± 25.4	80.3 ± 2.1
6/11 - 7/16	87.2 ± 2.4	73.1 ± 3.3	80.2 ± 3.8	73.2 ± 4.8
5/14 - 7/16	47.5 ± 22.8	72.1 ± 3.7	71.1 ± 9.2	66.9 ± 9.5

TABLE 6 Percentage of mortality in three- and five-year-old black spruce grafts which were repotted without or with root pruning before heat treatment at different stages of shoot elongation.

Treatments	Grafts without root pruning		Grafts with root pruning	
	3 yrs. old	5 yrs. old	3 yrs. old	5 yrs. old
Outdoor controls	16	20	6	15
Indoor treatments				
5/14 - 6/18	0	5	3	10
6/11 - 7/16	0	0	0	0
5/14 - 7/16	9	0	9	35

(R.H. Ho and O. Hak)

A Combination of Heat Treatment and High Humidity in a Greenhouse

A pilot study was carried out to explore the effect of heat and high-humidity treatment on cone crops. Ten ramets each of five five-year-old grafts were repotted into 15-litre pots before treatment which began a week after lateral vegetative bud burst. The first set of 10 grafts was treated for four weeks. The second set had the same period of treatment but was brought in three weeks later. The third set was brought in at the same time as the first set and was treated for seven weeks. The indoor controls were brought into a greenhouse and shipped out at the same time as the third set. The outdoor controls were left outdoors and cultivated as for the indoor controls and treatments.

For the treatment, a plastic tent was built in the greenhouse with a photoperiod of 18 hours. Temperatures averaged 40°C (48°C-30°C) during the day and 20°C (18°C-24°C) at night, and humidity averaged 90%.

The results are shown in Table 7. Heat treatment promoted seed-cone production, while a combination of heat and high humidity was not effective. Heat treatment alone and a combination of heat and high humidity appeared to promote pollen-cone production. Over 70% of the indoor controls and grafts treated with heat and high humidity produced cones, averaging about 100 pollen cones per graft, while 50% of the outdoor controls produced cones, averaging 16 cones per graft.

TABLE 7 Average number of 1987 seed and pollen cones per graft (±SE) in five-year-old black spruce grafts which were repotted before heat and high humidity treatment at different stages of shoot elongation.

Treatments	Seed cones		Pollen cones	
	% grafts producing cones	Average	% grafts producing cones	Average
Outdoor controls	83	7.3 ± 3.9	50	16.0 ± 10.9
Indoor controls	80	82.0 ± 36.3	80	99.0 ± 56.7
5/24 - 6/20	57	3.6 ± 1.6	71	98.6 ± 51.1
6/13 - 7/11	33	0.3 ± 0.2	100	138.3 ± 65.2
5/24 - 7/11	17	1.7 ± 1.7	83	108.7 ± 61.5

(R.H. Ho and O. Hak)

Biotechnology

In Vitro Culture of Explants from Mature Black Spruce

All conifers go through phase changes, from juvenile through transitional to the mature phase. The juvenile phase, lasting about 15 years or less from seed germination, is characterized by the conifer's inability to reproduce under natural conditions, its readiness to form adventitious roots, and its capability in organogenesis *in vitro*. The mature phase is opposite to the juvenile phase in these three characteristics.

Progeny testing is necessary to provide data for superior genotype selection and for evaluation of the parents for their combining ability. The period of a progeny test may last for 15 years or more. By the time the potential of the trees is realized, they have reached maturity and have begun to reproduce. Although cuttings from some genotypes can be rooted, the rooted cuttings perform like mature trees and often exhibit plagiotropism. Grafting of scions onto juvenile rootstocks often does not restore juvenility. Strategies have been developed to prolong juvenility by hedging, but these trees often lose their juvenility before the selection.

Rejuvenation of superior genotypes followed by vegetative propagation would be useful for the production of planting stock for reforestation. Tissue culture has been used to produce adventitious shoots from explants of mature conifers. Repeated subculture of the adventitious shoots has been reported to result in rejuvenation of some conifers. The present study is designed: i) to regenerate adventitious shoots from explants of mature black spruce, and ii) to root the shoots to produce plantlets for juvenility testing. The study is a COFRDA-funded project.

Adventitious Root Regeneration

Twigs with dormant buds were sampled from a 35-year-old tree in October, 1986, and a from 15-year-old tree in December, 1986 and February,

1987. Bud scales were removed from both terminal and lateral buds, and embryonic shoots were cut below the crown region of each bud and soaked in autoclaved distilled water for an hour before sterilization. The sterilized embryonic shoots were then incubated on one-half strength of Gresshoff and Doy medium (1/2 GD) supplemented with 2 mg/L 2,4-dichlorophenoxyacetic acid (2,4-D) and 0.2 mg/L naphthaleneacetic acid (NAA) for one to eight weeks before being transferred onto the medium without any plant growth regulators. After a month on the medium without any growth regulators, the shoots were transferred onto 1/2 GD medium with 1% activated charcoal and without any growth regulators. Thereafter, the regulator-free 1/2 GD medium with and without charcoal was used in alternate months for culture of the embryonic shoots. The cultures were placed in a growth room with a 16-hour photoperiod and temperatures of 25°C during the day and 15°C at night.

Rong Ho regenerated this plantlet from an adventitious shoot of mature black spruce.

Adventitious roots were initiated in the embryonic shoots incubated on 1/2 GD medium supplemented with 2,4-D and NAA for two to eight weeks.

The roots were regenerated after the shoots were transferred onto 1/2 GD medium without any growth regulators. Two types of root regeneration were observed: 1) roots regenerated from the axillary areas of leaf primordia or the cortex on the basal part of embryonic shoots, and 2) roots developed by differentiation of the leaf primordia on the basal part of embryonic shoots where they were in contact with the medium. Twelve to 14% of the embryonic shoots from the 35-year-old tree produced roots from the leaf axillary areas or the cortex after two to four weeks of incubation on the medium with growth regulators. Nine to 19% of embryonic shoots from the 15-year-old tree produced roots only from leaf primordia when the shoots were incubated on 1/2 GD medium with growth regulators for five to eight weeks in December; the percentage decreased with the increasing period of incubation. When embryonic shoots from the same tree were incubated in February, 4% of the shoots produced roots from the leaf axillary areas after three weeks of incubation on 1/2 GD medium with growth regulators, and 2% from the leaf primordia after eight weeks of incubation. The different types of root regeneration and different response of the embryonic shoots could be attributed to the age of the trees and to sampling in different months of the year.

Adventitious Shoot Regeneration

In addition to trees selected for adventitious root regeneration, four other trees were included in this study; three of them were 25 years old and one was 15 years old.

Twigs from one or two trees of each age were collected in August, October, December, 1986 and January, February and April, 1987. Buds collected in August had not completed their differentiation, while those sampled in April were swelling but had not emerged from the bud scales.

Embryonic shoots prepared for culture were as described in adventitious root regeneration. The shoots were cultured on each of 1/2 GD, GD, and Quoinin and Lepoivre (LP) media, each supplemented with 5 mg/L benzylaminopurine (BAP) and 0.2 mg/L NAA, for one to eight weeks before they were transferred to the respective media without any plant growth regulators. A month later, the embryonic shoots were transferred onto the respective media with 1% activated charcoal and without any growth regulators. Thereafter, the media with and without charcoal but lacking growth regulators were used alternately for monthly transfer. The cultures were maintained in a growth room with a 16-hour photoperiod and temperatures of 25°C during the day and 15°C at night.

Adventitious shoots were initiated in the embryonic shoots incubated on any of the three media supplemented with growth regulators for one to eight weeks. The adventitious shoots were regenerated after the embryonic shoots were transferred onto the media without growth regulators. Regeneration often occurred from the axillary areas of leaf primordia on the embryonic shoots. Any axillary areas had the potential to produce an adventitious shoot, although the adventitious shoots were more frequently regenerated from the basal and distal areas of an embryonic shoot.

The second type of regeneration was the differentiation of a leaf primordium into an adventitious shoot primordium which grew into a shoot.

The third type of regeneration was the differentiation and organogenesis of a callusing leaf primordium into adventitious shoots.

The percentage of embryonic shoots producing one or more adventitious shoots ranged from 0% to 83%, based on the number of embryonic shoots incubated on a medium per treatment period per month. The best treatment period appeared to be four weeks on either GD or LP medium with growth regulators, while one week seemed to be sufficient when 1/2 GD medium with growth regulators was used for culture of the embryonic shoots. When the treatment period was longer than four weeks, callusing of the embryonic shoots often occurred, and only a few would differentiate and organize to produce adventitious shoots, which did not grow well and died before they were cut for rooting.

Embryonic shoots collected in August and April responded to the treatment of plant growth regulators in the media as well as those collected in October, December, January and February. However, the regenerated adventitious shoots on the embryonic shoots in August and April collections

did not grow well: most died after three months of culture. October to February appeared to be the best time for twig collection, as the embryonic shoots regenerated many adventitious shoots. About 50% of the adventitious shoots survived the subculture on 1/2 GD and GD media after three months of culture, while over 80% of the shoots survived the subculture on LP medium.

Many adventitious shoots had been harvested for rooting after they had grown to about 2 cm in length. Although adventitious roots had been regenerated on embryonic shoots, rooting of the adventitious shoots had not been successful in a medium supplemented with NAA, 2,4-D, indoleacetic acid, indolebutyric acid or a combination of any of the two auxins.

(R.H. Ho, A.Y. Raj, M.A. Baird, W.J. Gibbs)

Hardwood Tree Improvement

Black Locust, Black Alder, Black Walnut: Species Introduction and Improvement

Considerable effort has been made to assemble propagation material from superior selections for sexual and vegetative propagation. Sources include European, Asiatic and American natural stands and seed orchard phenotypes.

Trees are classified and evaluated according to the following characteristics:

1. Occurrence: location, distribution, altitude, economic importance
2. Site requirements: precipitation, humidity, temperature, soil type, physical and chemical soil characteristics, soil depth
3. Tree features: light requirements, morphology, crown, form, buds, stem, root type, reproduction, seedling characteristics, competitive power, susceptibility to injury
4. Silvicultural management: reproduction, cloning

In mid-March, a new batch of black locust, black alder and black walnut seed was sown in tubes, brought into a lath-house and subsequently set out in open nursery beds for hardening. The tubelings will require another growing season before outplanting.

Black locust and black alder gene pools are close to attaining the breadth and quality needed for effective stock improvement. The two nitrogen-fixing species can be used effectively as allelopathic nurse crops and cover crop components (natural precursors and early associates) to optimize the performance of valuable hardwood species such as black walnut, white ash, black cherry, red oak or basswood which would otherwise be difficult to establish. Such variable associations would expand the range of planting sites to include lowlands and low-productivity replant areas.

Select black locust and black alder from over 100 sources are set out at

Orono, Vespra and other locations near provincial nurseries for evaluation in progeny/provenance tests. Stock meeting specific criteria can be selected and propagated for particular purposes, especially black locust, a tree of exceptional durability showing a strong tendency to retain parental characteristics. Several methods have proven successful for vegetative reproduction of desirable stock.

Locust proved virtually free of borer, particularly on well-tended areas and close to agricultural crops where alternate host vegetation (goldenrod and other composites) are minimal. Preventive pruning of infested branches and stems also helped to minimize insect infestation. One of the most outstanding features of black locust foliage is its reported repellent effect on gypsy moth, a characteristic which can be utilized to protect plantations of other species with a black locust "surround" or buffer zone.

In provenance/progeny trials, plantations of select European alder (3 000 trees) have been established in several locations to be maintained as gene banks. One of the largest trials was established as a co-operative project with Ganaraska Conservation Authority and Orono Provincial Nursery. Special alder selections were set out in protective plantings at the nursery.

At Orono, superior progeny of northern black walnut provenances are being set out, more each year, and maintained for scion production and grafting. This multidistrict project is directed at the preservation of superior individuals in danger of removal, which would lead ultimately to the loss of valuable and unique germ plasm. Annual decapitation of surplus walnut stems results in the formation of vigorous propagation stools not unlike those of poplar.

Introduction of select sources of valuable fast-growing species will ensure a continued supply of quality biomass. Fast-growing nurse crops will provide a wide range of ecological benefits and help defray stand establishment and tending costs early in the rotation.

(P. Jaciw)

Hybrid Poplar Breeding

Hybrid Poplar Energy Survey

Populations developed from selective breeding of fast-growing female clones with high-energy male clones were screened for energy productivity, and additional progeny were selected for clone development. A comparative planting of parental clones and selected offspring clones will be established to determine the apparent gain from selective breeding. Occurrence of *Septoria* infections in some progeny suggests that further hybridization (back-crossing) and selection will be necessary to minimize susceptibility to this pathogen.

(H.W. Anderson)

Alla Herzan measures the performance of selected progeny of red oak planted between rows of European alder.

Aspen Clonal Study:
Association of Micro-organisms within Trees

A chi-square analysis was used in an attempt to delineate associations of ecological significance in the occurrence of pairs of micro-organisms within the trees sampled during the aspen clonal study. Strong associations among yeasts, bacteria, *Peniophora polygonia*, and the occurrence of no organisms, as well as the non-association of these four with other organisms, revealed a definitive time sequence for the occurrence of certain organisms. However, within a specific time-frame, the relationships among the organisms revealed a complex of associations that, while interesting, are unintelligible based on current knowledge of the organisms.

(D.H. Weingartner)

Poplar Clonal Collection Evaluation

In 1987, observations and measurements made in the poplar clone collection at OTIFBI headquarters in Maple at the end of three growing seasons were summarized.

This collection is maintained as a stool bed and is cut every year to the ground.

Foliage infestation with *Melampsora* spp. (rust) was assessed to evaluate the degree of reduction of the effective growing season for the clones affected. It was noted that, depending on the date by which the attack involved most of the foliage, the effective growing season of the most sensitive clones was reduced by about 35%. Rust infestation is affected by environmental conditions, which change from year to year. Rust assessment studies revealed the need for an improved method for assessing the infestation. In the future we hope to improve the objectivity of this assessment through the use of video imagery which will allow non-destructive assessments of infested areas over time.

Height-growth performance was also assessed. The different clonal potential for growth was very clearly manifested when not influenced by rust attack, as for clones immune to the disease. During growing seasons of similar length, some clones grew over four metres, while others reached only about two metres. While maintaining their relative ranking, all the clones with healthy foliage appeared to be affected in a similar fashion by the atmospheric environment, particularly by solar radiation. A case in point is the 1986 growing season, which happened to be very rainy. The heights attained in 1986 were inferior to the heights attained by the same clones in both 1987 and 1985. Although during the 1986 growing season an abundant precipitation regime satisfied well the high water requirements of poplar, the season's incoming solar radiation was reduced by about 18% due to cloudiness and cloud opacity. This resulted in an average reduction in height growth of about 24% for 1986, compared with 1985.

(C.S. Papadopol and A. Pratchett)

Potential Growing Season Duration for Hybrid Poplar

The expansion of exotic species into new regions must be based on a thorough climatic assessment of the new place of culture to reveal any essential conflicts that might arise between local sites and species requirements. Whenever a group of highly productive botanical entities such as hybrid poplars are tried in new environments, different from the areas in which they are already well proven, a pretest ecological analysis should be performed. Such an analysis could compare growing season duration, growing season limits, and active height-growth interval.

It is well known that the limits of the growing season are under strong thermal control. Not known, however, are the thermal thresholds that trigger the phenological phases of poplar in Ontario. In order to determine these, phenological observations were made in Maple starting in 1983, and analysed together with daily air temperatures. For these observations, the growing season was considered to extend from bud break in the spring to colour change

of leaves in the fall, while the active height-growth interval was considered to have ended with formation of the terminal bud. A preliminary conclusion of this analysis was that the start of the growing season for hybrid poplar should be considered the day when the average daily temperature remains between 8°C and 10°C for at least five consecutive days. Bud break may occur even shortly before, if the maximum air temperature reaches high values during cloudless spring days: the dark brown colour of buds may accentuate local heating well beyond the air temperature. Bud colour seems to be the explanation for the break of floral buds of poplars two to three weeks before the break of foliar buds. For poplar clones unaffected by foliar diseases, the end of the growing season occurs roughly at the end of the first five-day interval with an average daily temperature of less than 5°C. The period with active height growth begins with the appearance of first leaves from the terminal bud and ends in early August.

At that time of year, several consecutive dry days usually occur in conjunction with a very clear nighttime atmosphere. During such nights the air temperature may fall close to 5-8°C, although during the daytime it may climb again to 22-27°C. About three to five days after a succession of cool, cloudless nights, the new terminal bud appears as a green cone on top of the shoot, among new leaves that cease to develop.

These thermal limits are still approximate, varying slightly between clones, and are influenced by the sudden or slow heating/cooling pattern of the year. Once known, thermal limits can be applied to multi-annual weather information from several localities in an attempt to determine typical local growing season characteristics, such as: start/end dates, duration, thermal, radiation and pluvial regime, saturation deficit, atmospheric demand for evapotranspiration and the degree of satisfaction of this demand by rain.

Figures 1 and 2 present the evolution of air temperatures in Richmond Hill, Ontario, for the interval April 1 to October 30 for the years 1986 and 1987. Important phenological phases are marked on the graphs. Figure 3 shows the normal daily temperature to which the thermal thresholds have been applied to obtain the limits of the growing season.

An analysis of this kind applied to several years in succession for each locality revealed a variability up to three weeks in growing season duration. When these thermal thresholds are applied to daily data files for various years in a north-to-south transect, the duration of the growing season for poplar appears to increase from about 120 days in Thunder Bay to about 190 days in St. Williams.

These findings may be applied to a number of other species and should be related to productivity studies to arrive at an optimum allocation of indigenous and exotic species.

(C.S. Papadopol)

Fig 1. 1986 Growing Season's Limits
for Hybrid Poplar in Maple

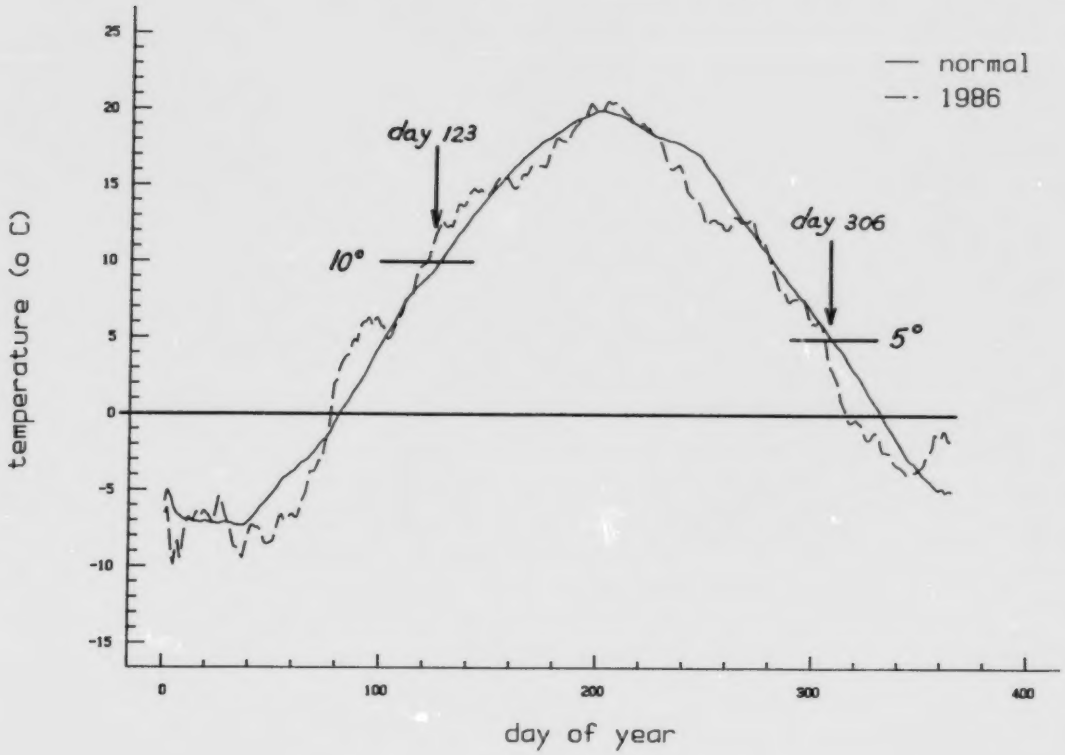


Fig 2. 1987 Growing Season's Limits
for Hybrid Poplar in Maple

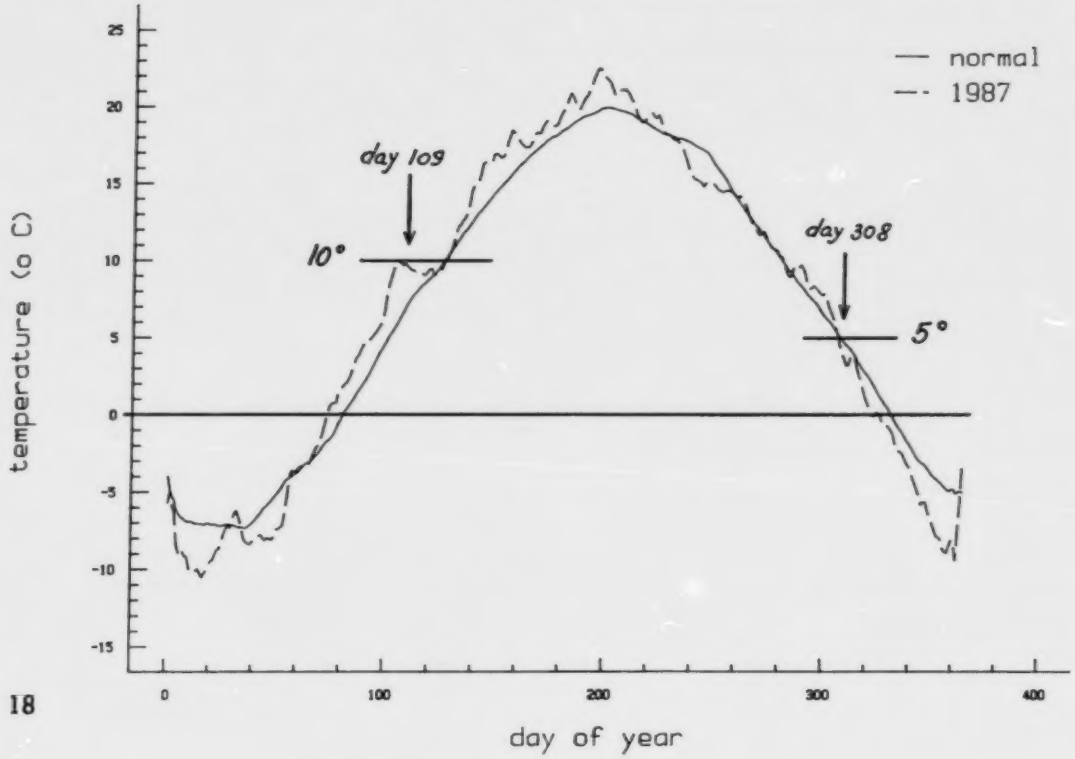
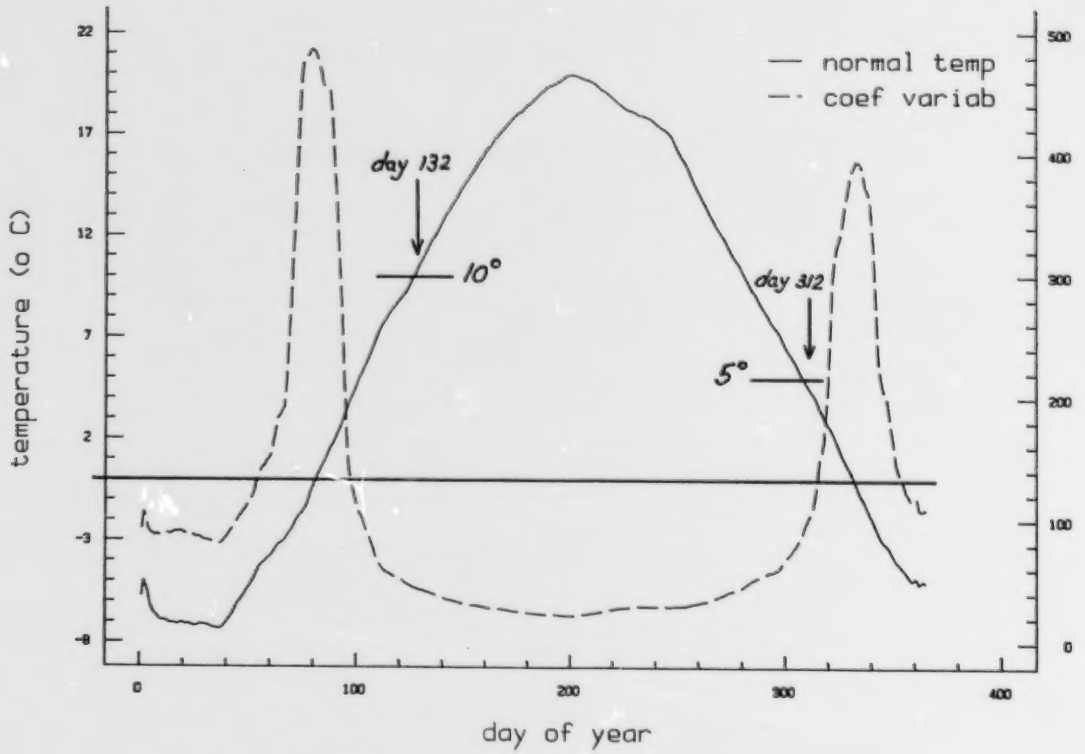


Fig 3. Multi-annual Growing Season for Hybrid Poplar in Maple



Spruce Breeding

Spruce Hybridization

Flowering in 1986 was even more disappointing than in 1985. Two breeding areas in Sault Ste. Marie and Simcoe Districts were again used. There were 63 tree x pollen parent crosses utilizing 96 ramets. Of these, 55 were interspecific crosses involving 11 species; three were tri-hybrid crosses; and five were hybrid backcrosses representing four species. Emphasis remains on the search for hardy and fast-growing hybrids for the boreal forest.

Previous crosses in this search have involved combinations of high-latitude *P. sitchensis* selections with good selections of *P. glauca* from central and northern Ontario. Further combinations were made in 1986 with *P. glauca* from Pagwa and Lake Superior selections. As with previous crosses, this seed is being banked until all combinations have been completed.

With the same aim, excellent selections of *P. omorika* and *P. sitchensis* were used with *P. mariana* from Black Sturgeon, Geraldton and Thunder Bay. This seed too is being banked until all combinations have been made. Success with the *P. sitchensis x P. mariana* cross is always very low; unfortunately,

results in general were somewhat limited by the low amount of flowering. Additional losses were incurred due to red squirrel depradations, particularly on the *P. omorika x P. mariana* crosses, and several combinations must be repeated. Success in other interspecific crossing was low as well because of the poor flowering year and animal depradations.

Norbert Lussier, Shirley Loeppky and Al Gordon at Batchawana Picetum near Sault Ste. Marie, site of many breeding experiments.

P. omorika was crossed successfully with *P. pungens*. Crossability was very low. This was a repeatability cross and is extremely difficult to make. There are only one or two other possible records.

Progeny of the Rosendahl spruce (*P. glauca x P. mariana*) crossed successfully with *P. rubens* (1%), and depending on parent, backcrossed poorly with *P. glauca* (.08%) and well with *P. mariana* (10%). *P. x lutzii* (*P. sitchensis x P. glauca*) crossed successfully with one *P. mariana* selection (08%), failing in another. *P. x lutzii*, confirming earlier attempts, failed with *P. glauca*, and also failed to backcross with one female parent of *P. sitchensis*, but was, however, successful (2%) with another.

Second-generation breeding has resulted in progeny from tri-hybrid and hybrid backcrosses. These were outplanted in the Bracebridge District in 1987. They are from crosses of fast-growing *P. omorika x P. rubens* parent

hybrids, originally made in 1970, which have nov been outcrossed with good selections of *P. mariana*, and these same parent hybrids backcrossed to the parent species *P. omorika* and *P. mariana*. Early results based only on nursery performance indicate, as expected, that variation is considerable, and that some will prove to be rapid growers.

(A.G. Gordon)

Red Spruce Seed and Breeding Orchards

The recognition of the value of red spruce for its wood quality, its silvicultural characteristics and as an interfacing species in forestry/wildlife management continues to increase. It is expected to be particularly useful in Site Region 5: parts of the Algonquin Region and the southern tier of Northeastern Region districts. A 20-source provenance experiment was evaluated in 1985, 25 years after establishment. The time period involved provides a very substantive test. Variation was sufficient to establish synthetic rankings of height and diameter. Utilizing this data along with other characteristics, selections were made in 1987. Scions from 83 trees representing 5% of the 2 000 plantation trees were taken and grafted at Orono Nursery. The remaining trees required for the orchard designs are being selected from wild plus-trees. Several of these were located in 1987.

(A.G. Gordon)

SEED RESEARCH

Seed Production

Monitoring Spruce Seed Production

Cone crop evaluations were continued in 1987. In cooperation with CFS scientists at Great Lakes Forestry Centre (GLFC), informal surveys were conducted over much of the range of black and white spruce in Ontario. No white spruce crop was identified anywhere in the province except for isolated single trees. Black spruce cone crops were obviously at a low point in their cycle. A potential moderate crop in the Northern Region was almost totally destroyed by a late spring frost while cone flowers were at a receptive—hence highly vulnerable—stage. Light crops were identified at some locations in the North Central Region, again substantially reduced by frost damage.

The erratic behaviour of crop production points to the need for more comprehensive information on yields by year, and on the factors contributing to those yields. This is particularly important in the north, where climatic factors have a disproportionate effect during the short growing period. Phenological observations are urgently needed. Flower initiation efforts have limited meaning in the north when good crops are destroyed or severely damaged, as has been the case with black spruce in the past two years.

A pilot program was initiated in 1987 to investigate the use of the TRIM system to identify years of seed production. Cones were taken from sample

trees of white spruce at Orono from which cone crops have been assessed annually since 1971. Detective work, however, is a second-best methodology for determining crop size and frequency. Past data on cone production in the Kimberly Clark seed orchard at Longlac is currently being compiled with data from later collections, re-initiated by OTIFBI/GLFC scientists. To this end, black spruce collections were made from each producing ramet in the Longlac orchard and MNR orchards in O'Connor Twp. and the Matawin area, as well as from seed production areas in the Nipigon district.

Seed data from black spruce clonal seed orchard collections have shown occasional anomalies which indicate either strong environmental differences between ramets of some clones or possible misidentification of individual ramets. Foliar samples were taken from some trees and isoenzyme evaluation of the 12 clones currently being studied was initiated.

(D.A. Skeates)

Seed Yield Information

A research report was published on yield information from several OTIFBI and GLFC studies. This provides data on cone and seed yields per tree and per hectare as well as yields of seed per hectolitre. The report also identifies many of the most important factors influencing yields of cones and seed. Data analysis was begun and proposals were prepared for further studies of these factors to provide an information base for managing registered seed sources to increase yields and improve seed quality.

Cone Size

Data on yield of seed and seed weight related to cone size was compiled for one study, and analysis was completed for a second. Individual tree collections from three study areas in 1979 were graded by cone size, and relationships were determined. The second study used clonal material from the Kimberly Clark seed orchard in 1982 and 1984. Individual cones from 72 ramets (6 ramets x 12 clones) were torn apart and total seed complement was counted. Data analysis is in process.

Extractory Technology

From past work in GLFC it is apparent that there is a considerable discrepancy between yields reported by different extraction facilities. A study was initiated to determine the reasons for differences. From preliminary data, it is apparent that seed source (ie. stand age and site), extraction methodology and cleaning methodologies interact to create widely differing yields. Bases for reporting, ie. total seed, cleaned seed, filled seed or viable seed, also contribute to the confusion. Data collection and analysis are in process.

Pollination

A black spruce pilot study was initiated to determine probable gains in yield due to controlled pollination. Should gains appear significant, a project is planned to develop technologies to increase yields of seed from existing seed orchards.

Nutrition

Black spruce foliar samples were taken from all ramets of the 12 clones being studied at Longlac. In cooperation with a consultant, a nutrient evaluation is being conducted based on standards developed in young seed orchards of northwestern Ontario. Nutrient levels are viewed as a key factor in the yield and quality of seed in seed orchards.

(D.A. Skeates)

Cone Collection Technology

Due to damage sustained by the Ontario cone tower, collections using this equipment were not possible in 1987. Poor seed years in the desired species minimized the information loss. With the cooperation of GLFC and assistance from the Algonquin Region, the Northeastern Region equipment development group agreed to put the tower back into usable condition. It is expected that the tower will be available early in 1988.

To date the tower has been used effectively for a variety of purposes. Interest has been shown by the Algonquin Region in its use for collection of yellow birch, and by the Ministry of the Environment for sugar maple seed. The equipment also has potential for collection of pollen from mature conifers to be used for controlled crossing studies in seed orchards. Plans have been prepared for such studies in 1988 as well as for facilitating the continuing monitoring of registered seed sources which have grown beyond ladder length.

(D.A. Skeates)

Seed Source Studies

White Spruce Provenance Trials

Establishment phases of cooperative studies on white spruce provenance variation between OTIFBI and Petawawa National Forestry Institute (PNFI) were completed in 1986. The program is now on a maintenance and assessment regime. In all, 17 experiments involving almost 200 sources of seed have been planted. The most recent planting in Kirkland Lake was measured in 1987, completing initial height assessments of all the district plantings. Five-year height assessments have been completed on all but the most recently established trials, while the earliest plantings will be ready for 10-year assessment in 1988.

Data on seed sources has been compiled and study outlines have been prepared. Analysis is currently under way of nursery data, initial heights in the field, and five-year heights, where available. To date, two experiments have been destroyed by fire, though one of these was eventually replanted. A third is of questionable value due to continuous severe frost damage. A work plan for future assessment schedules has been prepared and all surviving experiments will continue to be evaluated.

(D.A. Skeates)

Seed in Stock Production

Black Spruce Container Stock

Development work using pregermination or mini-container techniques to maximize seed utilization was terminated as an active project in 1986. Nevertheless, some effort is expended each year providing advice and assistance when requested. The use of germination plugs to provide replacements for empty cavities was tried by one black spruce grower in 1987, with some success. This is a specialized technology which requires different prescriptions from standard procedures in use for stock in paper pots. Though the systems developed at OTIFBI have potential both for refilling and for greater efficiency in greenhouse production of container stock, greater effort will have to be put into technology development before it can be applied. An internal report is in preparation.

Small-scale investigations were initiated with other,less commonly used species. It is expected that further work using germination plugs will be continued on a limited basis.

The problems of stocking in the greenhouse, length of growing period in expensive facilities and stock variability are still experienced by most growers. This technology of pre-growing at high density under controlled germination conditions still has considerable potential for reducing such problems and hence is worth further development effort.

(D.A. Skeates)

Black Spruce Accelerated Transplants

At the request of Thunder Bay Nursery, a seed sorting study was designed and materials prepared for a Castle and Cook container transplant operation. The purpose of the study was to refine seed usage in order to achieve close to full stocking in the greenhouse with single seed sowing. Inasmuch as the germinative vigour of the seed lot was high, and operational conditions in 1987 proved excellent, the study failed to achieve its objectives because almost complete success was achieved regardless of seed fraction. Data from Thunder Bay should be available in 1988.

(D.A. Skeates)

STOCK PRODUCTION

Cellular Physiology

Dormancy and Frost Hardiness

Determination of dormancy and frost hardiness in nursery stock is important because the best time for overwinter storage or for outplanting is when the stock is fully dormant and hardy. This increases survival and

subsequent growth after outplanting. Two approaches for dormancy determination are being tested: i) physical and ii) chemical.

Physical Techniques

Electrical impedance continued to be the most reliable physical method for determining when bare-root stock is ready to be lifted in the fall for overwinter frozen storage (at -3°C) in our provincial bare-root nurseries.

Favourable results from semi-operational nursery trials in the fall of 1986 at several provincial nurseries resulted in the implementation of the electrical impedance technique on an operational basis at Thunder Bay, Dryden, Swastika, Midhurst, Orono and Kemptville during the 1987 fall lifting season for stock going into overwinter frozen storage.

Preliminary electrical impedance safe-lifting zones for overwinter frozen storage have now been established for various species and climatic zones in Ontario. Impedance is corrected for diameter using $1/D^2$. Bench-mark corrected impedance values are 39 for black and white spruce in northern Ontario nurseries, and 35 for the same species in southern Ontario. A value of 35 is required for red and white pine and jack pine throughout the province. These values will continue to be "fine-tuned" to accommodate changes in stock types and in nursery cultural practices such as conditioning planting stock for overwinter frozen storage by root wrenching and/or root pruning.

Work is also continuing on the development of an operational manual to assist staff with the monitoring of electrical impedance in bare-root nurseries.

(C. Glerum, G.D. Racey and R.E. Hutchison)

Chemical Techniques

The chemical technique involves monitoring the seasonal patterns of amino acids within the seedlings using procedures described in earlier reports. The amino acid tryptophan, which exhibits significant seasonal trends such as increasing in concentration from September to December, is going to be developed as an indicator compound for determining the state of dormancy in the fall and/or spring.

Chemical concentrations and changes in dormancy stages as indicated by bud flush and growth are being monitored for overwinter frozen-stored black spruce and jack pine from Midhurst and Swastika nurseries. Every two weeks from October to May, trees are removed from frozen storage for growth testing and chemical extractions. Concentrations of amino acids and sugars are being monitored in the needles, bark, xylem and roots of the stored stock.

Preliminary results shov a change in dormancy throughout the test period, (i.e. decreasing dormancy with time), but at this point no clear correlations with chemical concentrations have been detected. However, the amino acid proline exhibits an increase in all tissue components of both species over the test period.

(Y.T. Kim, C. Glerum and D. Hickie)

Whole-Tree Physiology:
Nursery Stock Stress Resistance

Whether tree seedlings survive and grow with vigour after planting can frequently be attributed to how well nursery stock can withstand post-planting stresses. A major objective in our research programs is to quantify seedling stress resistance and to develop cultural techniques whereby stress resistance can be increased.

Plant Moisture Stress

Whereas nursery and field stock handling procedures are designed to minimize the exposure of nursery stock to stresses, seedlings are, nevertheless, on occasion exposed to desiccating conditions, and as a result may develop high levels of moisture stress between lifting and planting. One means by which levels of moisture stress in nursery stock may be evaluated is through the use of a pressure chamber, a field-portable and durable instrument which allows a rapid determination to be made of moisture stress at the planting site or in the nursery. In order to use the pressure chamber effectively, field staff must have guidelines which will indicate the level of moisture stress above which decreases in nursery stock field performance will occur. One such criterion is turgor loss or wilting point. The wilting point is a good measure of nursery stock critical moisture stress, because it varies seasonally with the ability of the stock to withstand desiccation. Practical methods by which the wilting point can be determined by nursery staff have been developed at OTIFBI.

Ideally, the wilting point would be determined directly at the nursery for individual stock lots as they are shipped. This information could form a part of the stock shipping record. Until such monitoring is implemented, however, it is possible to use as critical plant moisture stress values our research 'standards' for the relationship between stage of shoot development and the wilting point.

The wilting point has been found to vary seasonally in a manner consistent with changing shoot phenology, such that seedlings with dormant buds have a higher wilting-point plant moisture stress than do actively growing seedlings. Tables of standard ranges of the wilting-point plant moisture stress have been constructed for three-year-old white spruce (Table 8) and red pine (Table 9) bare-root stock and overwintered black spruce container stock (Table 10). As shown in Table 8, for example, white spruce bare-root seedlings normally have a wilting point in the range of 25 to 28 bars when buds are dormant, 20 to 25 bars when buds are swollen, and 13 to 17 bars when new shoots have elongated more than 5 cm.

TABLE 8 Relationship between the wilting point and stage of shoot development for 3+0 white spruce bareroot seedlings.

Stage of shoot development	Wilting point PMS (bars)
Dormant buds	25 - 30 bars
Buds swollen, none broken	20 - 25 bars
Buds broken average new shoot length: 3-5 cm	17 - 20 bars
New shoots longer than 5 cm	13 - 17 bars

TABLE 9 Relationship between the wilting point and stage of shoot development for 3+0 red pine bareroot seedlings.

Stage of shoot development	Wilting point PMS (bars)
Dormant buds	25 - 28 bars
Buds largely inactive, slight elongation	20 - 25 bars
Buds elongated average bud length: 5 cm	17 - 20 bars
Candles longer than 10 cm	12 - 15 bars

TABLE 10 Relationship between the wilting point and stage of shoot development for second-year black spruce container seedlings.

Stage of shoot development	Wilting point PMS (bars)
Dormant buds	25 - 30 bars
Buds swollen	20 - 25 bars
Buds flushed average new shoot length: 1 cm or less	17 - 20 bars
New shoots longer than 1 cm	14 - 17 bars

The wilting point could serve as an indicator of maximum acceptable moisture stress, so that the technician or forester in charge of a planting crew can decide whether to accept stock for planting. If stock at the

planting site exceeds the wilting point, the decision may be made to try to rehydrate the stock by soaking in well-oxygenated water, to reassign the stock to a more mesic (wet) site, or to plant at a closer spacing in the anticipation of a certain level of mortality.

The effects of plant moisture stress on outplanting performance were investigated in a trial using three-year-old white spruce bare-root stock which had been moisture-stressed and then planted at the Midhurst Research Station of OTIFBI. Third-year height of stressed seedlings averaged 47.8 cm and survival was 64.1%, compared to an average height of 49.2 cm and 77.5% survival of seedlings which were not stressed prior to planting.

(S.J. Colombo)

Drought-Conditioning Spruce and Pine Container Stock

Conditioning container stock by exposure to sustained water deficits can profoundly alter the water relations of seedlings, making them more tolerant of drought after planting. In growth-room and greenhouse trials with jack pine, white spruce and black spruce, seedlings were conditioned by withholding water until the predawn plant moisture stress (PMS) was at least 14 bars. Drought conditioning enabled seedlings, particularly their root systems, to sustain cell turgor to higher stress levels. Results obtained using pressure-volume analysis indicate that white spruce is more drought-tolerant (ie. able to maintain turgor at lower water potentials) than black spruce or jack pine, although all three species have the capacity for osmotic adjustment in response to water stress.

A trial in which black spruce seedlings were drought-conditioned in a greenhouse, and subsequently planted outdoors in sand-filled troughs under a canopy to exclude rain, resulted in reduced stomatal conductivity and transpiration and enhanced osmotic adjustment. After 20 days without water, seedling survival was 47% in normal production-run seedlings, compared to 91% in the drought-conditioned stock. Field ecophysiological monitoring of newly planted black spruce and jack pine seedlings indicated that drought conditioning reduces stomatal conductance and transpiration, allowing seedlings to conserve water during periods of drought and high evaporative demand. Results after the first planting season indicate that drought conditioning enabled seedlings to avoid damage compared to production-run stock after a period of no rainfall following planting. Trials to determine the intensity and duration of stress conditioning required for maximizing drought tolerance indicate that two or three successive drought cycles of moderate intensity (10-14 bars predawn PMS) may be as effective as one or more severe droughts (18-23 bars predawn PMS) in producing drought-tolerant seedlings.

(R.S. Koppenaal and S.J. Colombo)

Organic Solute Accumulation in Roots and Shoots of Drought-Conditioned Jack Pine and White Spruce Seedlings

The ability of tree seedlings to tolerate drought is largely dependent on their capacity for osmotic adjustment, a process which produces a favourable osmotic gradient for turgor maintenance through the cellular accumulation of solutes, mostly sugars and other organic osmotica. The

Ross Koppenaal uses a porometer to measure needle transpiration and stomatal resistance in jack pine.

measurement of organic solutes by gas liquid chromatography identified the predominant osmotically active constituents accumulating in shoots and roots of drought-conditioned (ie. water-stressed) jack pine and white spruce seedlings as fructose, glucose and galactose (in jack pine shoots only). Total organic solutes increased proportionately more in roots (2.7x) than in shoots (no increase) of drought-conditioned jack pine but increased almost equally in drought-conditioned white spruce roots (1.6x) and shoots (1.4x) compared to levels in unconditioned seedlings. Our results from pressure-volume analysis of conditioned and unconditioned seedlings show that when water is the limiting factor, the accumulation of solutes induced by drought conditioning increases the ability of seedlings to maintain cell turgor, which is essential for the continuation of physiological processes supporting survival and growth.

(R.S. Koppenaal and S.J. Colombo)

Development of Resistance to Winter Drying in Spruce Container Stock

Winter drying or desiccation is a major cause of mortality of container stock overwintered out-of-doors. Winter drying occurs when seedling roots are frozen but the shoots are exposed, especially when seedlings are exposed to strong winds and bright sunlight. While the severity of losses due to winter drying can be moderated to some extent by the use of artificial shade and windbreaks to protect trees in holding areas, we have observed in the past that seedlings which have been hardened under warm conditions are more resistant to damage from winter drying, while seedlings which are exposed to cold conditions during hardening are more susceptible to winter drying. Our hypothesis based on these observations was that seedlings which are exposed to cool or freezing conditions prior to maturation of the needles may not complete needle development properly, and may therefore be less well able to control water loss during periods of winter drying.

To test this hypothesis, black spruce container seedlings were placed in either a cool (19°C/7°C day/night temperatures) or a warm (26°C/18°C) hardening regime after bud initiation. Needles from within 1 cm of the shoot tip were collected at the time of bud initiation and seven and 14 weeks thereafter. Needles were examined microscopically to determine whether differences in anatomy could be related to temperature during hardening. In addition, stomatal and cuticular rates of transpiration were measured by porometric and gravimetric methods, respectively.

It was found that the cuticle, which covers the needle surface and is largely impermeable to water, was significantly thicker in seedlings hardened under warm temperatures. In addition, rates of cuticular transpiration were significantly lower in warm-hardened seedlings, while stomatal transpiration was significantly lower in cool-hardened seedlings. Under desiccating conditions, such as are found during periods of winter drying, warm-hardened seedlings appear to be better able to conserve moisture due to greater needle cuticle thickness and consequent reduced rates of cuticular transpiration. These results support the hypothesis that seedlings which are hardened under warm conditions are more resistant to winter drying as a direct result of more complete needle maturation. In the coming year we will investigate whether differences in cuticular and stomatal resistance which develop due temperatures during hardening affect the desiccation resistance of seedlings after planting the following year.

(S.J. Colombo and N.B. Vanhinsberg)

Container Seedling Production

Extended Greenhouse Culture and Root Hardiness of Container Seedlings

Most container stock in Ontario is prepared for overwintering using a hardening regime known as Extended Greenhouse Culture. According to this regime, seedlings initiate buds during late August to early September and are kept inside a warm greenhouse, protected from damaging frosts until high

levels of shoot frost hardiness are achieved. Regional frost hardiness testing laboratories are currently located in Dryden and Kirkland Lake, with a new laboratory to be established in Thunder Bay in 1988.

A major question is the amount of heating which crops should receive during Extended Greenhouse Culture. While shoots will become frost hardy to temperatures approaching -40°C without exposure to cold temperatures, and premature exposure of maturing needles to cold temperatures will cause seedlings to be susceptible to winter drying as described previously, it is also known that roots require exposure to cold temperatures to acquire high levels of frost hardiness. In 1987, trials were conducted to assess the effects of cold temperatures on the development of root frost hardiness by black spruce container seedlings.

In one experiment, seedlings grown in Spencer Lemaire 'Ferdinand' containers were placed into each of three temperature regimes for a seven week period following bud initiation. Temperature regimes were: i) warm (26°C/18°C day/night) temperatures throughout the hardening period; ii) three weeks of warm (26°C/18°C day/night) temperatures followed by four weeks of cool temperatures (10°C/5°C day/night), and iii) cool (10°C/5°C day/night) temperatures throughout the seven week hardening period. Root hardiness was assessed at the beginning of the hardening period and four or seven weeks later, using both diffusate-electrical conductivity and intact plant methods. Diffusate-electrical conductivity was assessed by washing the soil from the roots of trees to be frozen and placing the roots in test tubes. These roots were then frozen, along with the roots for the intact root freezing test, in which seedlings were removed from the Spencer Lemaire trays and planted in pots. All roots were frozen at a rate not exceeding 2°C per hour to each of a range of temperatures previously found to span the range of expected root frost hardiness. Root damage to intact plants was determined by visual estimation of the proportion of the root system which was dead, or, in the diffusate-electrical conductivity test, by measurement of proportional electrolyte leakage, in which the greater the degree of freezing damage, the greater the increase in leaching of electrolytes from the roots.

Results of the diffusate-electrical conductivity tests indicated that the level of electrolyte leakage associated with root freezing damage varied depending upon the temperature of the hardening regime; therefore, this technique could not reliably be used to compare differences in root hardiness between treatments. The intact root freezing tests, on the other hand, allowed comparisons between treatments. The lethal temperature to 50% of the root systems (LT50) at the end of the hardening period was between -7°C and -11°C in seedlings which did not receive any cool temperature exposure. In contrast, seedlings which received either three or seven weeks of cool temperatures prior to freezing were equally hardy, with LT50s between -11°C and -15°C. Frost hardiness increased to below -19°C following a further two weeks exposure to cool temperatures.

(S.J. Colombo)

Bud Dormancy of Black Spruce Container Seedlings

Bud dormancy can be defined as the rate at which buds flush and shoot growth resumes when the dormant plants are placed in an environment conducive

to shoot growth. Information on dormancy of seedlings of the common species and stock types produced in Ontario is generally lacking, despite the fact that bud dormancy is known to be closely related to frost hardiness, resistance to environmental stresses, and the ability of nursery stock to survive frozen storage without damage. We have therefore been conducting studies of the factors affecting bud dormancy in black spruce container stock.

In one trial, we examined the effect of photoperiod (8, 12, 16, 18 or 24-hour photoperiods) and time since bud initiation (varying sampling dates relative to the time of bud initiation) on the rate of bud flushing of first-year black spruce container seedlings. Approximately 20 seedlings were placed into each of the photoperiods weekly from the time of bud initiation, and were examined twice weekly thereafter to determine the proportion of the seedlings to have broken bud and to have resumed shoot elongation.

Both photoperiod and time since bud initiation greatly affected the rate of bud flushing in first-year black spruce container seedlings, with most rapid bud flushing occurring in seedlings exposed to 24-hour photoperiods and with the longest time since bud initiation. Nine weeks after bud initiation, seedlings took respectively 35.0, 28.0, 16.4, 15.6 and 5.9 days to reach 50% bud flushing when exposed to photoperiods of 8, 12, 16, 18 and 24 hours duration. To test the effect of cold temperatures on dormancy, another group of seedlings was placed in cool storage at +2°C on week nine, a treatment known to break dormancy in other tree species. Following four weeks in cool storage, seedlings were placed into the growth test environment to determine the rate of bud flushing. Seedlings which received four weeks of cool storage reached 50% bud flush under eight-hour photoperiods after only 5.2 days. One conclusion from these results is that both photoperiod and temperature are extremely effective at relieving dormancy. These findings contribute to our understanding of dormancy in first-year black spruce container seedlings. Information of this type can be used in the development of procedures for frozen storage of this stock type, as well as being of direct use to managers of container seedling nurseries.

(S.J. Colombo)

Bud Initiation in Greenhouse Black Spruce Production

Bud initiation is the first visible sign of a number of morphological and physiological changes that occur in black spruce seedlings. Although photoperiod is the most important environmental stimulus to begin bud initiation, other environmental forces such as temperature and plant nutrition can modify the effect.

In research to date, temperature has been found to have the greatest influence on the speed of bud initiation in greenhouse-grown seedlings exposed to bud-inductive photoperiods. In growth chamber tests utilizing a simulated daylength decline for September 1 at 48°N latitude and 40 different day-and-night temperature combinations, fastest bud initiation was attained (15 to 22 days) when the night temperature was between 10°C and 24°C. When the night temperature either was less than 10°C or was greater than 24°C, bud initiation was not observed in all seedlings until 29 to 43 days. Day temperatures had no effect.

In greenhouse operations, droughting is frequently used in conjunction with other stresses as a means of inducing bud initiation in spruce crops. However, the efficacy of this treatment is not clear. Experiment results so far indicate that when daylengths are kept long (e.g. 18 hours), no level of droughting will aid in inducing bud initiation. Future experimentation will determine whether an interaction exists between drought and daylength.

The effect of plant nutrition on bud initiation is also under study. In one experiment, seedlings were treated with various rates of fertilizer for periods up to five weeks before exposure to natural (bud inductive) photoperiods. No difference in the rate of bud initiation was observed. However, in another study, seedlings were either fertilized at a normal rate or were leached and watered only, and were exposed to natural daylengths for July 1, August 1 or September 1. Only when seedlings were exposed to July 1 photoperiods was a difference in the speed of bud initiation observed. Seedlings receiving fertilizer applications set bud later than did those receiving water only. It is possible that an interaction between photoperiod and plant nutrition exists. Investigations will continue to examine this potential interaction more closely.

To test for long-term effects from greenhouse bud-initiation regimes, operationally overwintered seedlings were planted at the Midhurst Research Unit of OTIFBI and were closely monitored for bud flushing, shoot elongation and bud initiation in the first season of field growth. Seedlings from short-day bud-initiation regimes flushed sooner in the spring and set bud later at the end of the first field season than did seedlings from natural-daylength bud-initiation regimes. As a result, the growing season for short-day treated seedlings was approximately four weeks longer than for seedlings from natural-daylength regimes. The effect of an extended period of shoot growth on frost-hardiness development in the field is yet to be determined.

(K.D. Odlum and S.J. Colombo)

Outplanting Performance of Coniferous Planting Stock

Tamarack and European Larch Storage

Fifth-year growth and survival results from three separate overwinter-storage trials (1976-1979) show that a program of fall-lifting larch and tamarack for overwinter frozen storage would provide high-quality planting stock without the logistical problems of lifting prior to bud flush in the spring.

(G.D. Racey and R.E. Hutchison)

Sprayable Latex Mulches

Mulching is widely used in forest tree nurseries. However, mulches are not normally used in forest regeneration. In 1987, analysis was carried out on the results of a 1985 trial conducted to evaluate some of the effects of sprayable latex mulches on: i) a plant's growing environment; ii) nursery

seedbed stabilization; iii) seed germination rates; and iv) seedling performance after outplanting.

The results of the study demonstrated that the desirable properties of moisture retention, temperature enhancement and soil stabilization can be achieved with sprayable latex mulches. These properties were desirable in theory, but could not be detected statistically or biologically as leading to significant improvements in seedbed or field performance of common conifer trees. In addition, the cost as well as the absence of a suitable spraying technology indicate that sprayable latex mulches have a limited, if any, role at this time in the forestry applications tested.

(G.D. Racey and R.E. Hutchison)

Greenhouse vs. Standard Transplants

Kirkland Lake District

The third-year field performance data on greenhouse and standard black spruce transplants was collected during the fall of 1987.

Although data analysis is still to be completed, field observations in the third growing season indicated that the G + 1-1/2 and standard 1-1/2 + 1-1/2 stock types were outperforming the G+1 stock. The 1-1/2 + 1-1/2 stock type also appeared to be producing more foliage mass than the greenhouse transplants, which could be an early indication of better establishment.

Based on field performance data analysed in year two and field observations in year three, G + 1-1/2 stock type appears to be a viable alternative to 1-1/2 + 1-1/2 stock. Trees will continue to be monitored, and a report will be prepared after five years of field performance.

Kapuskasing District

First-year data was analysed and second-year data collected during the fall of 1987. The first-year data was similar to that presented for the Kirkland Lake plant, in that 1-1/2 + 1-1/2 and G + 1-1/2 stock were outperforming the G+1 stock.

In this study, performance of frozen-stored stock and fresh-lifted stock were compared. Excavations of root systems after one growing season indicated more root growth for all frozen-stored stock types when compared to fresh-lifted stock. Future survival and growth of frozen stock is expected to be superior to that of fresh-lifted stock.

Annual monitoring will continue for an additional three years; reports on field performance are to be written after five years.

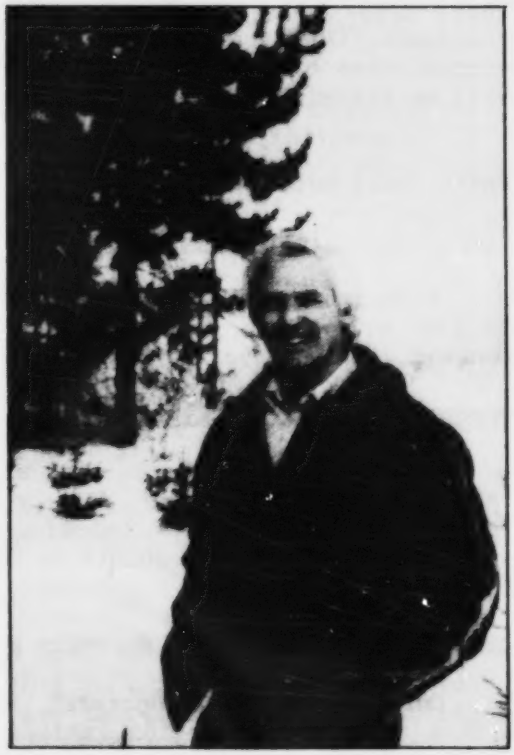
(J. Paterson)

Performance of Current-Crop Black Spruce

The quantity of container stock needed to satisfy planting requirements necessitates the use of several production schedules. Crops can be grown in three ways: as a current crop (sown in February, lined out under shades in

May and planted in June and July); as a single overwinter crop (sown in May, lined out in late July for hardening and overwintered in the same location); or under Extended Greenhouse Culture (sown in June and grown in the greenhouse until mid-August, followed by conditioning practices to promote dormancy and frost hardiness prior to placing outside for overwintering).

There appears to be considerable opposition to the use of current-crop seedlings for planting: field staff report that the seedlings "don't grow" after being planted, and do not, therefore, compete vigorously with other vegetation. To respond to this concern, we investigated the ontogeny of current-crop black spruce seedlings after outplanting. Four hundred current-crop black spruce seedlings were planted on a site dominated by tall-grass competition. Since it was also of interest to ascertain the effects of competition and of the presence of the paper container on seedling response, one half of the seedlings were planted and maintained under weed-free conditions, while the other half were allowed to grow among grass competition. Within each competition level, seedlings were planted either with or without the paper container around the root mass. Seedlings were evaluated after the first and second growing seasons. A subsample of seedlings was further evaluated by carefully excavating root systems and determining root development.



Keith McClain

Results show that while seedlings did not increase in height (as expected) during the remainder of the growing season after planting, significant increases in total seedling dry weight were observed regardless of level of competition and presence or absence of the paper container. At the end of the second year, seedlings grown under weeded conditions were taller than those in the non-weeded area; the presence or absence of the paper pot made no difference to height increment. Root development in terms of root area index and root dry weight were significantly greater for seedlings in the weeded area and for seedlings planted without the paper container around the root ball. Total leaf area was affected only by competition level, being greater on the weeded plots.

This study indicated clearly that, under normal field conditions, current-crop black spruce seedlings grow appreciably after planting, and that carbon allocation is primarily to the stem (significant increases in diameter) and to the root (significant increases in root area index). Removal of the paper container can result in greater root development, but does not

appear to influence leaf area. It is speculated that increased availability of soil water and nutrients and increased incident radiation due to the removal of competing vegetation provide conditions favourable for increased crown development and photosynthetic capacity. It is anticipated that during the third growing season (second period for shoot elongation), seedlings with greater crown and root development will exhibit significant increases in shoot elongation relative to seedlings of smaller crown and root dimensions under conditions of competition, and possibly the presence of the paper container. The hypothesis that early favourable establishment conditions for current-crop black spruce seedlings enhance successive performance potential will be tested in future investigations.

(K.M. McClain)

Operational Outplanting of Multiple-Leadered Spruce

Timmins District: White Spruce

Assessments during the fall of 1987 (fifth year) were not completed due to snow conditions. Measurements will be taken during the spring of 1988 and results will be reported by the end of 1988.

Dryden District: Black Spruce

A decision was made to have assessments on this study delayed until the fall of 1988. Fifth-year data will then be collected and analysed, and reported. These reports, showing performance of multiple-leadered black spruce over five years, should be completed during 1989.

(J. Paterson)

Careful-Planting Trials: Northern Region

During 1986, the Northern Forest Development Group (NFDG), located within the Northern Region, established as part of their mandate the Stock Production Development Activity (SPDA). The SPDA was formed to identify existing research knowledge in stock production and to identify areas needing further research. Stock standards and early plantation performance were the main themes of a meeting to address stock production issues held in Timmins on December 1-4, 1986, involving input from growers, clients (both FMA Industries and MNR Districts) and researchers. The consensus which evolved from this meeting was that it would be difficult to establish stock standards for the production of stock without knowing how these standards influenced plantation performance. During the winter of 1987, planting trials were designed for implementation during the spring of 1987; the trials were to involve stock produced within the Northern Region planted in operational trials and careful-planting trials. Our involvement was as scientific advisors on the careful-planting-trial portion of the regional planting trial series.

The goals of the Northern Region are:

1. To provide a common, defensible, verifiable data base for discussion of stock standards;

2. To provide management information on the relationship between stock standards and early plantation performance to enable calibration/adjustment of both growing and planting systems.

This comprehensive trial series is being conducted over a five-year period and consists of three parts: i) the careful-planting trials for container stock; ii) the careful-planting trials for bare-root nursery stock; iii) the client trials involving both MNR districts and FMA Industries (see following report by K.M. McClain).

The careful-planting trials are viewed as controls in the trial series, and are expected to show the potential trees have for establishment. All private growers within the region are represented in this study with both overwintered and current container stock being tested. The bare-root portion of the study is testing both standard 1-1/2 + 1-1/2 transplants and G + 1-1/2 greenhouse transplants.

With improved stock production technology that will arise out of these investigations and in association with gains in other areas of silviculture, the Northern Region is confident that the following goals relative to survival and growth can be achieved for black spruce.

Survival	85-95%
Growth	(Current Annual Increment (cm/yr)
Year 1	10 cm
Year 2	20 cm
Year 3	30 cm

Results to date from the careful-planting series have shown that stock presently produced within the region does have the potential to reach these targets. Operational trials, however, have not shown this to be the case.

During the first of five years of investigations, 9 800 container stock and 4 655 bare-root stock were established in the careful-planting series. Total heights, annual increments, stem diameters, micro-site descriptions and competition (type and degree) were assessed in the first year after planting. Analysis of the interactions of site and competition on establishment will be tested and reported both regionally and in scientific papers. Results from this study will have influence on future silviculture treatments and cultural techniques for the growing of stock within the region.

(J. Paterson)

Client Planting Trials: Northern Region

As described above, the regional meeting on "Stock Standards and Early Plantation Performance" held under the auspices of the Northern Forest Development Group, Timmins, set broad research goals leading to the establishment of client planting trials in the Northern Region in 1987. The trials were guided by the following objectives: i) to delimit the field performance of selected nursery stock types produced in the Northern Region; ii) to determine annual variation in seedling performance in relation to

growing regime and climate (over five years); and iii) to determine the performance stability of selected stock types produced in the Northern Region.

Essentially, 20 nursery stock types each of black spruce and jack pine were planted in 10 separate plantations located throughout the Northern Region in predetermined planting zones delineated for each species. Five plantations of each were established in a randomized complete block design with four replications and 20 plots, to which stock types were randomly assigned. One hundred seedlings of each stock type represented the experimental unit. Sampling parameters consisted of survival, total seedling height, current annual increment and health condition. In 1987, the first of five yearly plantings of 80 000 seedlings was carried out. Analyses on the first year's data have been conducted by species within planting zones. Further analyses to test for stock-type x planting-zone interaction will treat entire planting zones as blocks. A non-significant interaction would indicate that stock types have similar performance potential regardless of planting area. If this proved to be the case, in times of stock loss, surviving stock lots could be transferred regionally with some confidence that growth of the future stand would not be jeopardized. Furthermore, savings would result because prepared sites would be utilized as planned.

Since rankings of seedling performance can change over time, plantations will be monitored yearly for five years and analysis conducted to test for significance of the stock-type x time interaction.

(K.M. McClain)

Tree Volume in Relation to Planting Time and Stock Type

In 1975, test plantings were initiated to ascertain the performance patterns of four stock types planted at biweekly intervals throughout the frost-free season in northern Ontario. Both seedlings and transplant nursery stock were used for the test plantings. One half of the nursery stock for each planting time was either removed from cold storage (spring lifted) or freshly dug from reserved beds at the Thunder Bay Forest Station. Seedlings across all sites were carefully planted and monitored. Eleven years after planting, seedlings were measured in an appropriate fashion to allow calculation of tree volume using the paracone volume formula (see R.R. Forslund, 1982, Can. J. For. Res. 12:215-221). Analysis of the data revealed that time of planting and stock type markedly affect volume production. For example, when comparing planting times for the four stock types that remained above 70% survival after 11 years, stem volumes varied according to planting dates: by 218% for spring-lifted and stored 1-1/2 + 1-1/2 transplants, by 370% for 3+0 seedlings, by 62% for fresh-lifted and planted 1-1/2 + 1/2 transplants, and by 80% for fresh-lifted and planted 2+0 seedlings.

These data provide strong evidence that despite acceptably high survival of planted seedlings, the method of handling and time of planting are critical with respect to future volume production. The data also suggest that greater variation in volume production is inherent in spring-lifted and stored stock than in fresh-lifted stock. This is likely the result of reduced vigour due to deferred planting (prolonged cold storage).

Although stock type differences with respect to time of planting were apparent as early as two years after planting (e.g. survival and current annual increment), the significance of these early differences becomes abundantly clear as trees mature. The consequence of deferred planting is reduced total volume per unit area at a specified rotation age, or significantly longer rotation ages for the attainment of predetermined volumes. Something as simple as deciding when to plant now emerges as central to the management planning process. The importance of planting time is further amplified with the movement toward prime site management. Consider the loss in tree volume production on Ontario's best sites if planting is conducted at the wrong time with respect to the physiology of the nursery stock and site resources!

(K.M. McClain)

Determination of Seedling Vitality and Prediction of Field Performance of Containerized Black Spruce and Jack Pine Seedlings

As a result of the substantial loss of containerized seedlings in the North Central Region in the spring of 1987, a monitoring program was established to ascertain the vitality of seedling stock lots throughout the overwinter period of 1987-88. In conjunction with this monitoring program, a greenhouse pot trial was initiated with the objective of determining a set of performance parameters that would help predict field performance. The basis of the trial is to determine the biomass production of seedling stock lots under conditions of no water stress and of increasing soil water deficit. Both regimes were evaluated at the point where 50% mortality occurred in the dry regime. The hypothesis tested was that as seedlings are held in storage, their ability to endure increasing soil water deficits decreases. Should this hypothesis be shown to be valid, it will be further hypothesized that seedling stock lots with low biomass production rates will exhibit relatively poorer performance potential than those with higher biomass production rates. In an outplanting trial planned for the spring of 1988, seedlings will be planted on two sites with contrasting moisture regimes. If through regression analysis a predictive model is found, immediate benefits will be derived: it will become feasible to eliminate suspect seedling stock lots from shipping schedules, allowing only high-quality seedlings to reach the planting site.

(K.M. McClain)

Nursery Water Management

Soil Hydraulic Conductivity Assessment of Nursery Soils

Transport processes for soil water and dissolved solids in the unsaturated zone (vadose zone) are of considerable importance for balancing water and nutrients, particularly for shallow crops growing on the permeable soils typical of nursery crops. The grower is faced with the challenge of maintaining steady access of roots to water and nutrients in spite of the very active transport processes.

Soil hydraulic conductivity is a measure of the ease with which water

flows through the particles that form the soil matrix, subject to gravity forces. The higher this value, the greater the flow rate. At the same time, the higher the soil water content, the greater the drainage.

Routine measurements of soil hydraulic conductivity include various laboratory and *in-situ* methods. Laboratory methods are not, however, applicable to sandy nursery soils, because the integrity of the soil sample cannot be preserved: repacking procedures drastically change the natural porosity. Field methods such as the ring cylinder infiltrometer, the air entry permeameter and the double tube are plagued with theoretical or practical limitations which often lead to low accuracy and reproducibility. The complexity of equipment, long time and large amount of water needed for a determination, as well as the need for skilled operators, represent additional drawbacks to *in-situ* methods. Still, the need to obtain reliable and representative values for soil hydraulic conductivity is crucial to any meaningful soil-water budgeting study and to the application of simulation models to phenomena involving water and nutrient transport processes.

Over the past five years, significant progress has been made at Guelph University, where the concept of *constant head well permeameter* has been developed, first into an analytical theory, and then into a device for *in-situ* measurement of field saturated hydraulic conductivity and sorptivity. The device has now been patented and is sold commercially by Soilmoisture Inc. under the name "Guelph Permeameter".

Determinations of field saturated hydraulic conductivity were performed in five provincial nurseries (Chapleau, Thunder Bay, Midhurst, Kemptville and St. Williams) in various areas judged by nursery superintendents to be characteristic of the range of conditions found at that nursery. Over 200 measurements were made. The results obtained varied considerably within every nursery, with the greatest range in Thunder Bay. The values obtained for saturated hydraulic conductivity were typical of sandy soils, from coarse to fine. They indicate the time that water (from rain, snowmelt or irrigation) resides in the soil-water reservoir. Sometimes the values within a single compartment were up to three times greater than the average value for the area. Thus the water balance of a certain nursery crop might be very different from one compartment to the next; correcting for this condition through irrigation may not always be possible because of the increased leaching triggered by more abundant irrigation.

Currently, the only known economical means of increasing the length of residence of water in the root zone is soil amendment with peat moss. This is only a palliative, however, because peat moss decomposes completely in about three years. Performed in a grid over the territory of a nursery, soil hydraulic conductivity measurements may greatly help nursery technologists to decide where and in what amounts to apply peat moss to decrease the initially high conductivity of coarse sand. This characteristic mapped for a whole nursery may give considerable help in crop allocation. It will also allow us to reconstruct the water balance of a certain crop during the growing season, with the rain and irrigation inputs to which it was subjected, showing when the crop experienced water stress and how significant that stress was. Using the soil water transport model developed at OTIFBI under COFRDA project 33505, such an analysis can be performed now, based on

physical characteristics of the soil and on a file (daily or hourly) of water inputs. Figures 4 and 5 present the precipitation regime and the soil suction head at 15 cm depth for two contrasting months. June 1982 was a month with abundant and almost regular rain, while July 1983 was very short of rain. The corresponding suction heads clearly reflected the precipitation regime. Soil water was easily available to seedlings during June 1982, when it was held at low suction values, while it was quickly depleted in July 1983 and therefore unavailable for the rest of the month. The behaviour of the soils considered in this analysis (Soil 1, sandy and highly permeable; Soil 2, loamy and with moderate permeability) was almost similar when rain was abundant. However, the permeability greatly influenced the local soil-water balance. Figures 6 and 7 depict the water flux through the bottom of the root zone for both soils in the same months. The permeable soil displayed a sizable percolation amount after every rain, while the loamy soil retained most of the water. In a rainy month, from a total precipitation of 112.6 mm, the sandy soil lost 76% of it through percolation while for the loamy soil this loss amounted to only 12%.

(C.S. Papadopol)

Nursery Soil Leaching Studies

The movement of water and solutes through the root zone of nursery crops plays an essential and complex role. An advanced growing technology has to provide crops with a steady supply of water and nutrients, particularly during June to August, the most active growth interval. However, variable precipitation regimes and highly permeable soil may contribute to the quick disappearance of nutrients from the root zone as a result of either heavy rains or abundant irrigation. It is obvious from studies of water movement in porous media that the movement of solutes through soil is related to the soil texture and to the amount of water percolating through the soil. A review of literature on this subject did not reveal any statement of an equation which would permit the quantitative estimate of nitrate movement as a function of the factors upon which it is dependent: texture, initial concentration of nitrogen fertilizer and amount of percolation water.

In order to obtain insight into the relations among these factors, a test bench with six percolation columns was built. The columns, filled with soil from various nursery compartments, will be "fertilized" with current nitrogen dosages and subjected to simulated rains. The leachate will be collected, measured and analysed for nitrate content. The test bench will be operated with a system of computerized valves which will permit the real regime of precipitation during a growing season, read from a historic precipitation file, to be duplicated on the column. The test bench, which will be operational in 1988, will allow data to be obtained from nitrogen-budget studies with reference to the root zone. It will also permit experimentation with various irrigation and fertilization regimes with a view to minimizing nitrogen leaching. Testing samples of soil from various nursery compartments will probably yield valuable cultural indications. Although built to duplicate transport processes in the root zone of a typical nursery crop, the test bench can be used for ecosystem studies by expanding the thickness of the layer considered to about two metres and increasing the displacement time considerably.

(C.S. Papadopol)

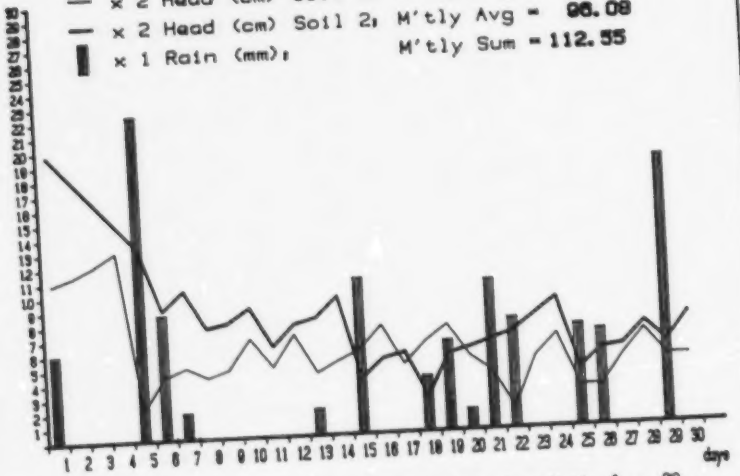


Fig. 4 . Precipitation and soil suction head at 15 cm depth, June 82

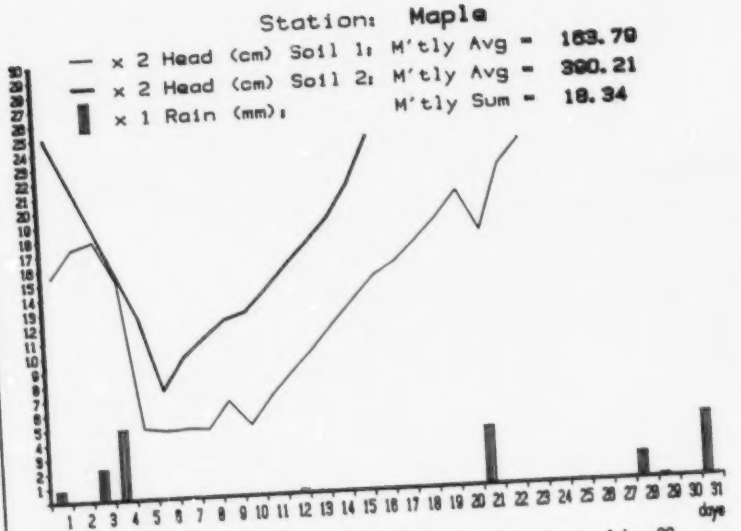


Fig. 5 . Precipitation and soil suction head at 15 cm depth, July 83

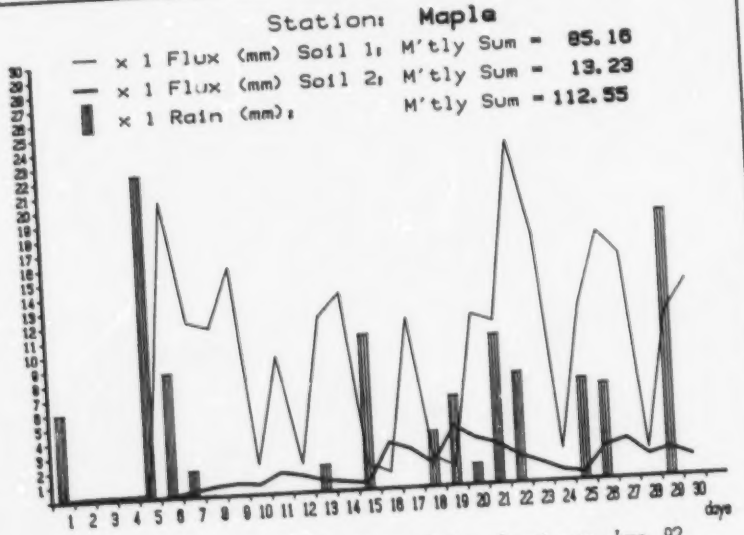


Fig. 6 . Precipitation and flux through bottom of root zone, June 82

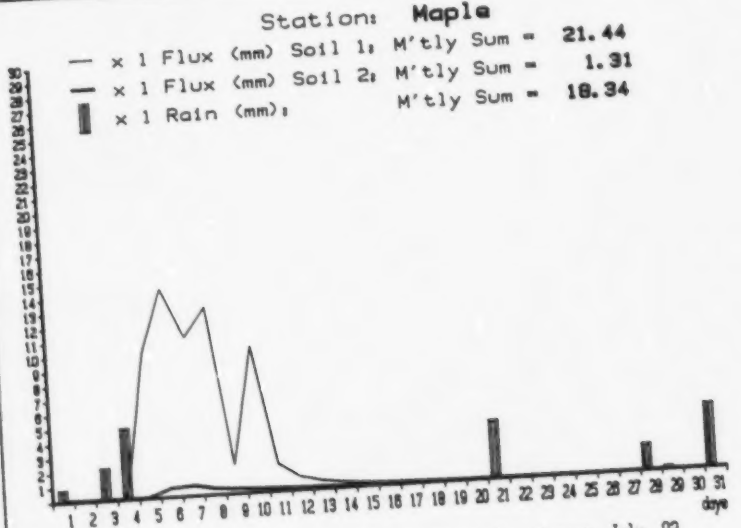


Fig. 7 . Precipitation and flux through bottom of root zone, July 83

New Software for Weather Data Collection at Nurseries

As a follow-up to COFRDA Project 33505, a number of improvements have been made to the weather data-collection systems installed at some nurseries, namely: i) telephone connection for remote access of data; ii) expanded sensors configuration; and iii) elaboration of new software for the calculation of atmospheric demand for evapotranspiration.

With the cooperation of staff from Huronia District and OTIFBI, as well as from the Midhurst and St. Williams nurseries, these nurseries' weather data-collection systems have been allocated dedicated telephone lines and modems for remote downloading of data by telephone. The current operational procedure implies automated data transfer between the weather stations and the computers installed at the nurseries, with immediate processing. At the same time, data is downloaded automatically every day by OTIFBI's laboratory in Maple. The communication system now in place benefits from the Ontario Communications Network and makes it possible for any interested party to download the data. Although these weather data-collection systems were acquired initially for irrigation-rate calculation, they proved very useful for other objectives as well. It now appears that one of the most important uses of this data outside the irrigation season is related to the spray program for the gypsy moth. To be effective, the treatment has to be done when meteorological conditions are right. However, because Ontario's atmospheric environment is so variable, information about parameters essential for the spray–air temperature and wind–have to be collected and made available at short intervals. To take care of these increased requirements in the years to come and to utilize the higher capabilities of the computing devices now in use, in 1987 we started to collect/report data at intervals of ten minutes instead of one hour. Apart from providing timely information for the spray program, this new data-collection schedule will improve the precision with which the atmospheric demand for evapotranspiration can be calculated for both operational and research objectives.

Interest has been expressed by some nurseries in expanding the configuration of sensors to obtain profiles of air temperatures, wind and soil temperatures. Given the potential of the 21 X Campbell Scientific micrologger, which forms the "brain" of these weather stations, expansion of the configuration of sensors is possible and desirable. To date, this expansion, which will allow measurements both at the standard height and at the crop level, is limited only by the cost of sensors.

With the change in the time interval for weather data collection, the software for the irrigation-rate calculation had to be changed to accommodate the significantly increased amount of data. A number of findings resulting from COFRDA Project 33505 also had to be incorporated into the new software. The current version of this software performs two functions: i) it calculates very precisely the atmospheric demand for evapotranspiration for a 24-hour interval, and ii) it allows for a comparison of conditions on a particular day of the year with days in the same calendar position, using long-term historic files for the same locality. For operational use, the computer program produces hard copies with weather data summaries, irrigation rates and operating times for the irrigation installation,

depending on spacing of sprinklers, nozzle type and operating pressure. At the same time, data for the previous 24 hours is made available for analysis using a system of sophisticated colour graphics. The same graphics can be obtained also as hard copies. Figures 8 and 9 (opposite) present the evolution of weather parameters and atmospheric demand for evapotranspiration.

Another computer program compares the most important weather parameters (temperature and precipitation) of a given day with the long-term files kept by the Atmospheric Environment Service for the same locality. Through a series of screen graphics, the analyst is informed about the range of variation for these parameters, the risk of frost at that date, the long-term probability of precipitation and the most probable amount of rain at that date. Figures 10 and 11 present the smoothed daily average temperature and the rain probability during the year for St. Williams.

Both computer programs, developed entirely at OTIFBI, are user-friendly and prepared for current EGA (640x350) and VGA (640x480) IBM computer standards. It is believed that their assimilation by nursery staff, already a fact of life at St. Williams and Midhurst, will increase the effectiveness of nursery operations and contribute to a better understanding of a crop's environment.

(C.S. Papadopol)

Estimation of Potential Evapotranspiration from Climatological Data and Reconstruction of Soil Moisture Regimes

Existing models for evapotranspiration calculation are used today mostly for the determination of crops' water requirements in an effort to save water and energy when irrigation is practised. However, some outstanding evapotranspiration models with daily resolutions may prove to be invaluable tools for reconstructing soil moisture regimes from appropriate climatic information. Using the excellent weather data archive of the Canadian Climate Centre of Environment Canada, as well as the soil-water transport model elaborated at OTIFBI under COFRDA Project 33505, a number of simulations have been run to reconstruct soil moisture availability for several localities during the growing season. Previous local determinations of soil hydraulic conductivities allowed for local calibration of the model.

Of the models tested for daily evapotranspiration calculations, the Penman and van Bavel formulas appear to be the most responsive to the environment's variations. Examination of the daily progression of atmospheric demand for evapotranspiration, precipitation and soil moisture concentration during monthly intervals allow determination of stress intervals in a more objective manner than from meteorological elements considered alone. From numerous experimental runs of the simulation model for soil-water transfer, it appears that moisture stress is more frequent and more acute on sites with a coarse texture where the time of residence of water in the soil water reservoir is short, almost regardless of the amount of rain. Also, it is obvious that growing conditions are better when the total sum of precipitation during the span of a month is distributed in numerous events more or less equally spaced in time, instead of fewer rain events with huge rain amounts.

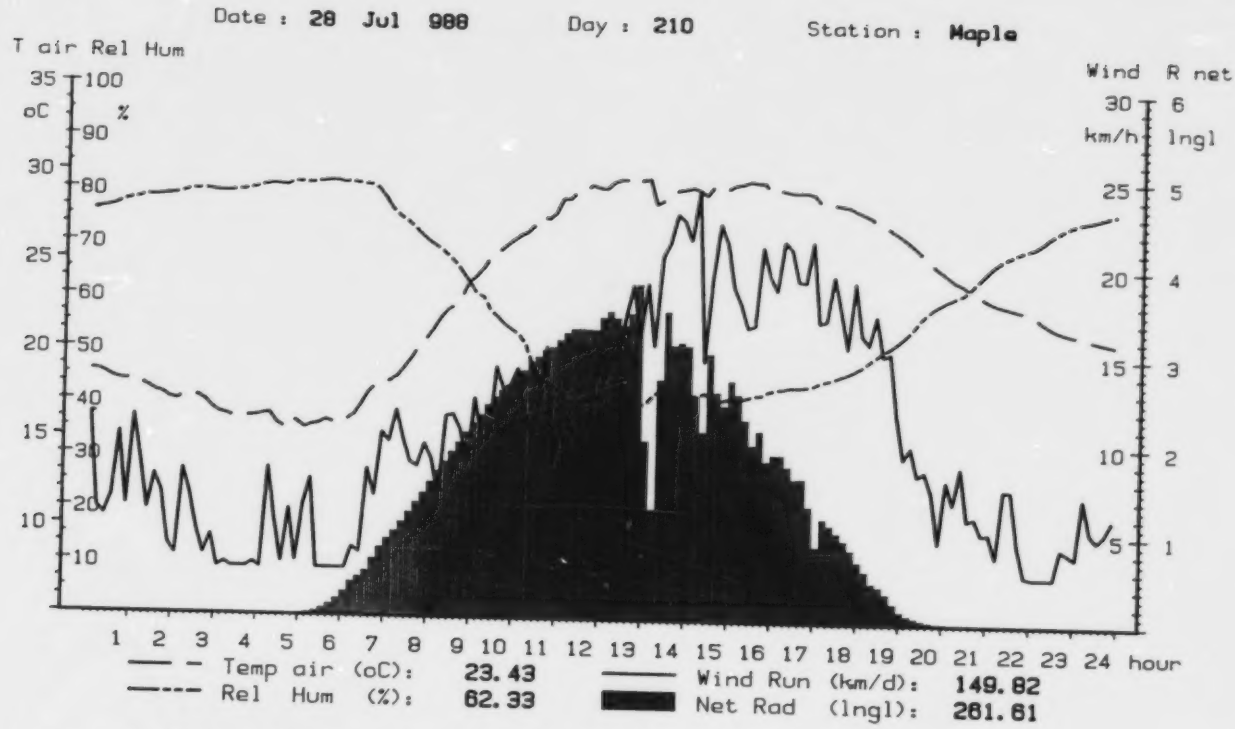


Fig. 8 . 10 minute variation of air temperature, relative humidity, wind speed and net radiation.

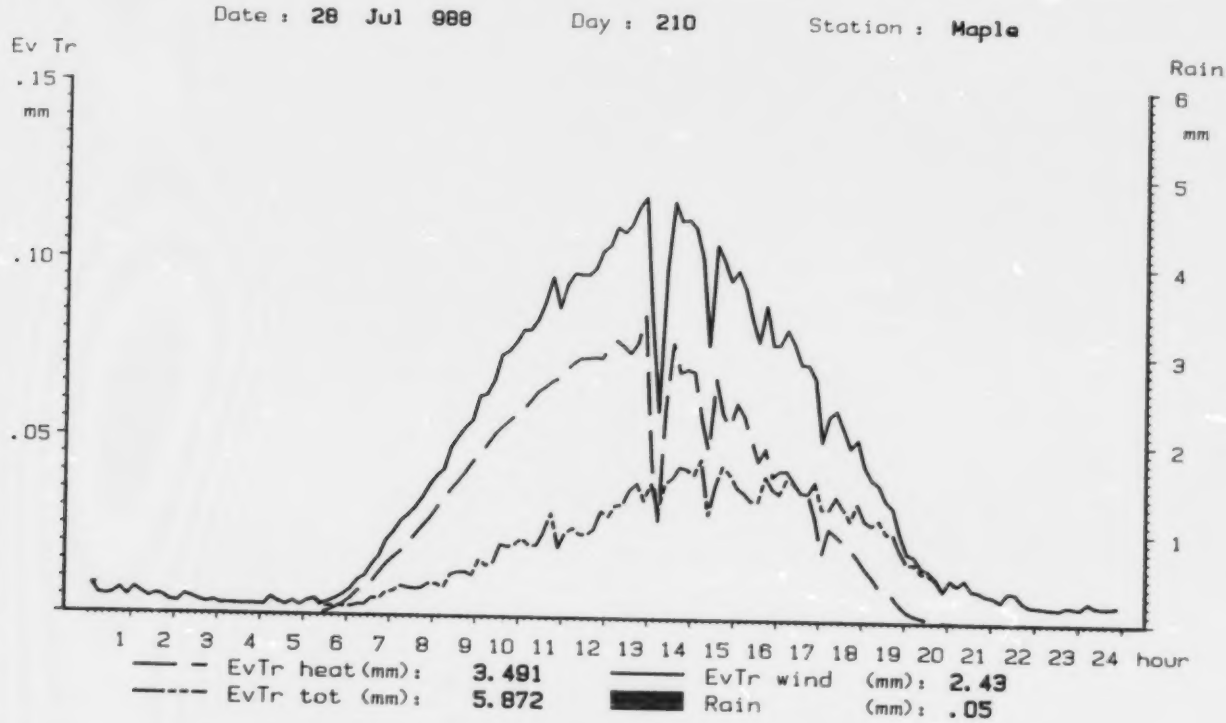


Fig. 9 . 10 minute variation of atmosphere's evapotranspirational demand.

Fig 10. Daily Normal Temperatures for St. Williams Nursery (1954-1984)

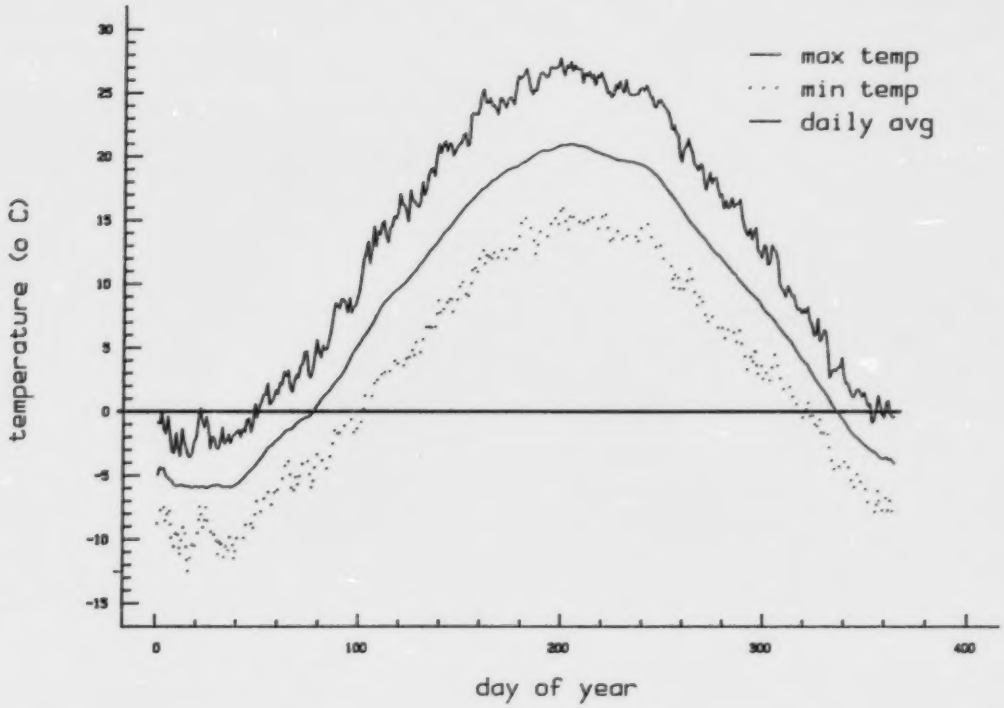
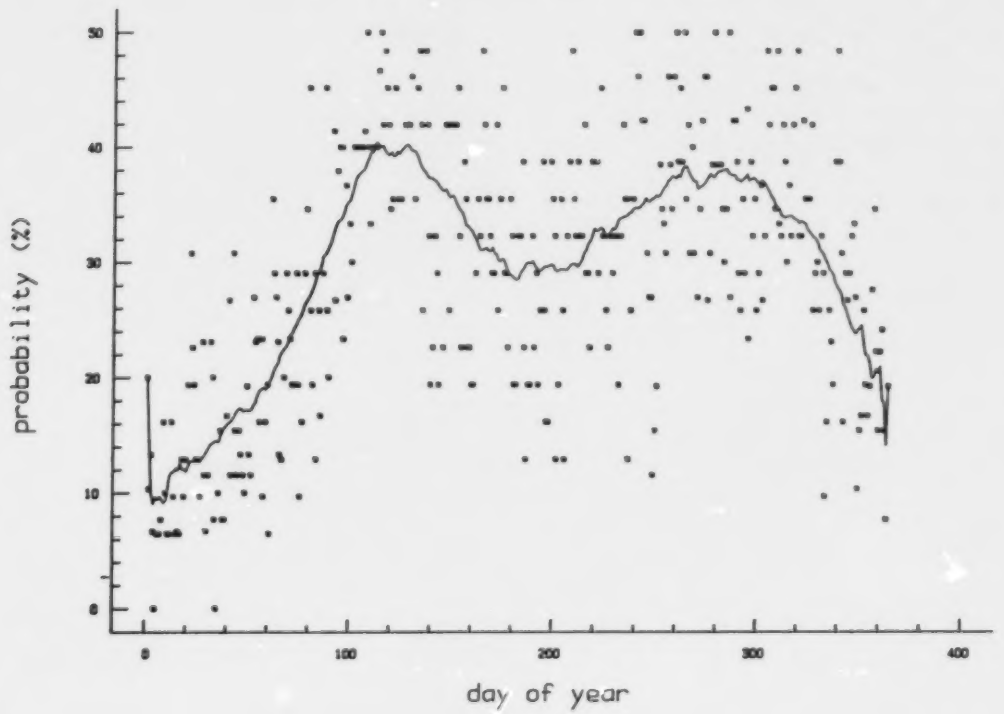


Fig 11. Smoothed Rain Probability for St. Williams Nursery (1954-1984)



In the future, the reconstruction of the atmospheric demand for evapotranspiration and of soil moisture regimes will be refined even further and related to seasonal growth measurements made with dendrometer tapes and strain gauges. The recent acquisitions of high-performance computer hardware (80386 micro-processor-based) with superior display capabilities will give a boost to these computation-intensive studies of growth ecophysiology. In order to increase the performance of the soil-water transport model even further, the option of rewriting it in ACSL language is being considered, while the existing graphic routines will be converted from Basic Compiler to Graphics Development Toolkit's C language.

Currently under consideration as a follow-up to these studies is the elaboration of a complex index of potential productivity based on daily weather inputs and calculation of the resulting soil moisture availability. This index will allow comparisons between years/localities and will contribute to a better explanation of how the environment controls tree growth.

(C.S. Papadopol)

REGENERATION

Rejuvenating Older and Damaged Stands

Yellow Birch/Sugar Maple Regeneration and Recruitment

Performance Modelling

Studies of stand dynamics in maple/birch/beech forests were continued in 1987. Historical census of growth and mortality of yellow birch regeneration in an experimentally logged area were updated, and back-projection computer programs were revised to allow use of any prism factor or sampling intensity. This study is directed to the development of a simulation model to evaluate production and regeneration strategies. Additional area was included in 1987 in which longer-term historical growth information is being measured from increment cores to analyze the cyclic nature of stand and tree growth over time.

A stem-quality inventory was begun in the Fall of 1987 (to be completed Spring 1988) regarding yellow birch polewood established by experimental logging in 1960. Distribution of crop-quality trees will be related to post-cut stand conditions such as stocking level, canopy cover and subsequent competition development, using computerized stand dynamics modelling. This will assist in the formulation of realistic silvicultural prescriptions with respect to subsequent value-growth, and will suggest strategies for tending schedules.

Species Interaction

Interspecific studies (maple/birch) of a preliminary nature were undertaken to examine possible allelopathic interactions which would account

for the failure of maple to re-establish under birch regeneration. Leaf and root samples are being analyzed for extractives for testing in a dose-response experiment with seedlings. The poor seed year in 1987 has delayed the testing phase until 1988.

(H.W. Anderson)

Red Oak Regeneration

The Value of Red Oak

Red oak is one of the most important species utilized in the hardwood product industry in Ontario. Top-quality red oak on the stump is valued at $235/MFBm compared to $85 for sugar maple. The values for sawlogs and veneer logs, respectively, are $400 and $875 for oak, and $250 and $450 for maple (Table 11). Red oak lumber and veneer sheets at the mill are worth $1 825 and $3 800 respectively.

The value of red oak lumber was up 18% in 1987. It has not reached its peak, and prospects for demand during the next 10 years look good. There is a higher demand for North American hardwoods in Europe and Asia, particularly for oak, because of the rationing of exotic hardwoods such as mahogany.

TABLE 11 Value of red oak compared to other species (Martin Logging 1987)

Species	PRODUCT ($/MFBm)					
	Saw Logs			Veneer Logs		
	At Stump	At Mill		At Mill		
	Grade 1	Grade 1	Grade 2	Grade 1	Grade 2	Grade 3
Red Oak	235	400	300	875	800	700
Sugar Maple	85	250	160	450	400	275
Yellow Birch	-	-	-	615	560	490
White Pine	160	325	250	-	-	-
Black Spruce	30	115	115	-	-	-
Jack Pine	30	115	115	-	-	-
Balsam Fir	30	115	115	-	-	-

(Summarized from a report by Dean F. Johnson, Chief Forester, G.M. Martin Logging, Ltd., Harcourt, Ontario.)

Red Oak Planting and Sowing

Trials of planting nursery stock under shelterwood continued in the Algonquin Region. Survival is high, but the free-to-grow stage of seedlings will likely depend on the incidence of deer browse and quality of competition control. Assessments in the early 1990s should provide conclusive answers. Results from two red oak plantations were summarized and published (*Growth and quality of red oak planted in a jack pine plantation*, OMNR Forest Research Note No. 44; *Growth and quality of red oak planted in red pine plantation openings*, OMNR Forest Research Report No. 117.)

George Stroempl compares the growth of natural and planted red oak in an opening in a jack pine plantation in Hendrie Forest. The oak on the right was planted eight years ago; the oak to its left is natural.

Pilot trials with acorns in kraft tubes planted under shelterwood, in strip-cut hardwoods and in pine plantations were carried out in the spring and fall in the Algonquin and Central Regions. The development of seedlings in tubes was about 65% in the first year. The light-textured soil used in the tubes and depth of planting the tubes were the two main criteria identified as the reasons for mortality. Sowing trials will continue.

Red Oak Regeneration Demonstration Area

Red oak is one of the major species, natural and planted, to be found on the J.W. Walker forest estate near Uxbridge, Ontario. The first plantings of red oak were carried out on the estate between 1918 and 1922. Red oak on sites with or without clay material in the subsoil show marked growth differences, favouring the former. This well-tended 75-year-old natural stand of red oak–white ash–sugar maple of superior quality underlines the advantage of carefully managing an ecologically ideal mixture to obtain timber of high economic value. MNR staff are invited to view the J.W. Walker estate as part of the red oak demonstration areas. In 1987, 22 MNR staff from the Algonquin and Central Regions toured the estate.

(G. Stroempl)

STAND MANAGEMENT

Hardwood

Thinning and Growth in a Sugar Maple–Ash–Basswood Stand

Seasonal progress in diameter increment is being recorded at annual intervals for about 300 maple, ash and basswood growing in a 50-year-old, even-aged woodlot near Chatsworth, Ontario. The stand was thinned experimentally in 1977-78, at which time the original basal area was reduced by 50% (heavy thinning) and 30% (light thinning). Growth and regeneration data show that hard maple responded best to heavy thinning; differences in growth rates between the lightly thinned and control plots were appreciably smaller. At the end of the 10-year period, surviving trees in the heavily thinned, lightly thinned and control plots had increased in diameter at breast height (D.b.h.) by 4.6 cm (1.8 in.), 2.8 cm (1.1 in.) and 2.3 cm (0.9 in.) respectively, and in basal area by 6.96 m^2/ha (30.3 sq ft/acre), 5.49 m^2/ha (23.9 sq ft/acre) and 4.91 m^2/ha (21.4 sq ft/acre) respectively. *Eutypella* canker was spreading rapidly, affecting 11% (21), 13% (46) and 15% (119) of the trees in the heavily thinned, lightly thinned and control plots. In the unthinned plots, natural mortality accounted for the loss of about 28% of all trees in 10 years.

Initial results of thinning the sugar maple–ash–basswood stand showed that heavy thinning appreciably increased the rate of growth of the residual trees, improved sanitation, reduced mortality and furthered vigorous hardwood regeneration. Ten years after treatment, the basal area of the heavily thinned, lightly thinned and control plots had increased by 65%, 42% and 31%, respectively.

Seasonal patterns of sugar maple diameter growth in the same stand were analysed for a number of years. Annual increments were measured with dendrometer tapes at biweekly intervals. Early seasonal increases prior to June 1 were not generally large (13% of average annual growth) and showed appreciable fluctuations associated with maximum and minimum spring temperatures. The greatest proportion of annual growth (36%) occurred in June, showing little variation from year to year. In July, diameter growth generally lessened (accounting on average for 31% of annual growth) and the appreciable annual fluctuations closely reflected prevailing soil-moisture conditions. The extension of the growing season into the fall and the rates of late seasonal growth appeared to be more closely associated with moisture stresses and seasonal soil moisture deficits than with prevailing temperature patterns.

Shortly after thinning, regeneration of all species was more abundant in the lightly thinned plots, which carried about 106 000 seedlings per hectare (43 000 per acre), and less abundant in the unthinned controls or in the heavily thinned plots, stocked with 25 000 and 42 000 seedlings per hectare respectively (11 000 and 17 000 per acre). Soon after thinning, the heavily thinned plots were overrun with dense vegetation which undoubtedly shaded out many seedlings; nevertheless, this treatment led to the greatest height growth in the long run. Thinning appeared to stimulate white ash regeneration, which averaged about 40% of the total in the thinned plots as compared to only 6% in controls. Natural regeneration of basswood was inadequate: the stand had to be underplanted to maintain its original composition. After a slow start, the growth rate of basswood rapidly increased, presently developing into a healthy understory component.

(P. Jaciw and H.W. Anderson)

Regional Liaison

The incorporation of the results of research studies into Regional and District management applications is an important final step in the scientific process. In many cases, methodologies developed or used by researchers can be valuable as management tools on their own. Considerable time was dedicated in 1987 to these aspects in the Algonquin, Central, Southwestern and Northeastern Regions.

In addition to timber marking courses related to tolerant hardwood management in Algonquin Region, contributions were also made to ANSI Technical Committee sessions in Southwestern and Central Regions with respect to decision models for silvicultural prescriptions for those forests of southern Ontario having special significance.

Participation in the Regeneration subcommittee of the Ontario Forest Research Council involved submission of a report dealing with research direction and priorities, both current and proposed.

Liaison continued with Algonquin Park District in connection with their tree-marking audit, sampling, and analysis system for Algonquin Park. Development of computer programs and training of staff in their use was continued.

The Algonquin Regional Growth Study initiated by M. McLean in 1977 involved some 250 permanent sample plots, which were remeasured by Regional staff using electronic data loggers and data capture/checking programs developed by Forest Biomass Unit personnel. This involved programming, staff training, and development of a data-base strategy. The results of this continuing study will provide reliable information for use in yield prediction and site productivity evaluation.

Revision of the Provincial Silvicultural Guides was begun in late 1987. The Forest Biomass Unit is providing "principal authorship" for revising the "Silvicultural Guide to the Tolerant Hardwood Working Groups" published in 1973 by including updated management philosophies and specific recommendations for silvicultural prescriptions based on a knowledge and understanding of silvics, site, yield potential, products and values, genetics, and environmental, wildlife and other non-timber considerations. The guides are scheduled for publication in late 1988.

(H.W. Anderson)

Softwood

Growth Responses of Four-Year-Old Conifer Plantations to Perennial Competition

The relationship between growth of planted stock and competing vegetation in early stand development is of critical importance. The major investments being made on tree improvement, stock production, site preparation, and planting produce little dividends if follow-up tending receives inadequate attention. The specific questions that are being addressed in this three-year study, funded by COFRDA, include:

1. Does crop tree growth respond linearly or exponentially to increased competition pressure?

2. Can low levels of competition be beneficial to the growth of planted conifers?

3. How does the growth response to competition pressure differ between species and stock type?

4. Is the relationship between growth and competition affected by site factors?

A total of 15 four-year-old plantations in the North Central region of Ontario will be sampled by the end of 1988. These plantations cover a wide range of soil textures and FEC site types. The sampling schedule is as follows: i) 1986 - three white spruce plantations (bare-root stock); ii) 1987 - six black spruce plantations (three bare-root and three containerized stock); and iii) 1988 - six jack pine plantations (three bare-root and three containerized stock).

From preliminary regression analyses on the data collected in 1986 and

1987, a good relationship exists between the percentage of open sky, obtained directly from fisheye photographs, and total seedling weight. The percentage of open sky gives an indirect estimate of the incident radiation each sampled seedling received. The use of covariate analyses, incorporating variables such as microsite and stock quality at time of planting, should help to reduce the coefficient of variation that currently exist for the tested regressions.

(D.M. Morris)

Mixedwood

Thinning Aspen in the Boreal Mixedwood Forest: Growth and Yield

Between 1979 and 1981, six aspen stands, aged five to 20 years, were systematically thinned. A preliminary look at incremental growth of four stands from one location revealed a strong association between growth and the chronological year, implicating the influence of annual weather patterns on stand growth. Graphs of individual tree growth within a plot resulted in the production of chaotic patterns, indicating that growth of an individual tree is fairly independent of the annual weather pattern. It was also apparent that growth and relationships between mensurational characteristics in the individual tree are greatly influenced by the stand structure.

It is anticipated that the development of effective growth models will be achieved only when the models are developed at the process level, rather than the typical least-squares regression fit.

(D.H. Weingartner)

Biomass Culture and Silviculture

Southern Ontario Upland Silviculture

The purpose of this program is to develop silvicultural techniques for the establishment of quality stands of mixed hardwood composition on upland sites and for the tending of natural stands to help meet MNR's production, recreational, environmental and aesthetic objectives. Southern Ontario is good hardwood country: its forest soils are productive and accessible, with high potential for the production of valuable species, many of which cannot be grown elsewhere in Canada.

Due to appreciable physiographic variability in southern Ontario, silviculturists are faced with a series of complex problems relating to species, stock quality, and pre- and post-planting treatments. To optimize results in this region, the upland program operates as a dual-crop forest system. Its purpose is to obtain early returns from fast-growing pioneer species and to provide an improved environment for the more tolerant timber

components.

The program includes the following fields of study, which are described in greater detail elsewhere in this review.

1. Tree Improvement and Biomass Culture. Location, propagation techniques, quality improvement and gene pool establishment of superior upland species for afforestation of downgraded stands.

2. Site Preparation and Establishment. Development of improved site preparation, testing of stock types, hardiness and planting methods for: i) high-yield, fast-growing monocultures, and ii) dual-crop, fine-timber stands in allelopathically compatible associations which will provide early returns, optimize yields and help meet industrial and ecological requirements.

3. Stand Management (Tending) Research. Development of advanced tending techniques for natural woodlots, cutovers and plantations to improve fibre yield and quality timber production and to ensure adequate regeneration of preferred species. The work involves thinning, pruning, spacing and the application of waste effluent to impoverished sites. Dendrometers are used to monitor growth for short-term evaluation of treatment effects and ecological conditions.

(P. Jaciw)

Hybrid Poplar/Willow Mini-rotations

Establishment Methods

Studies were continued on four separate experiments designed to confirm the value of horizontal or "flat-planting" as an effective establishment technique. All were harvested in late fall 1987 on a two-year rotation; oven-dry biomass, survival and size variables were measured. Results will be tracked on a historical basis to determine the longevity of such plantings in terms of diminishing yield.

Spacing/Clonal Studies

Two experiments at Vespra were continued to determine yield based on a two-year rotation. A poplar study compares five clones planted at three spacings in an unbalanced design. A second experiment compares eight willow clones at a single spacing. Both experiments were inventoried and harvested in late fall 1987 and will be reported in 1988.

(H.W. Anderson)

Modelling Methodology for Assessing the Biomass Accumulation Potential of Mini-Rotations

In a continuation of studies reported previously under this topic, an attempt was made in 1987 to elaborate a methodology by which the biomass

accumulation potential of rainfed poplar mini-rotations could be determined from estimated photosynthetic responses of the crop canopy to varying meteorological elements, mainly radiation, air temperature and precipitation.

The main assumptions considered by this modelling approach relate to the reduction of agroclimatic constraint indices involving moisture stress. These constraint indices are applied against the potential values of photosynthesis to estimate the attainable dry-matter yield.

A clonal component of this methodology proved more challenging than initially anticipated. Clonal performance appears to fluctuate greatly from one year to another, mainly for clones that are affected by foliar diseases. Because in some years the conditions for a disease's progression are very favourable, the effective growing season is curtailed at dates when the photosynthesis potential is still high. A preliminary conclusion of these studies is that only clones immune to foliar diseases, and therefore able to use the full growing season between its thermal limits, should in future be considered for the calibration of this model.

Apart from the possibility of predicting real crop yields, this methodology when completed will provide a land-evaluation tool for assessing the long-term capability of a land resource for fuel production from biomass.

(C.S. Papadopol)

Black Locust Coppicing Study

Work continued in a study of the effect of original stock size and rotation length on the performance of a black locust planting. Survival has been excellent since establishment in 1983, and coppicing ability has been good but variable in this non-clonal material. A complete analysis of data will be made following the harvest of the 1988 growing season (ie. after one complete cycle of rotations).

(H.W. Anderson)

Wastewater Utilization in Forestry: Seneca College

Fast-growing species augment the evapotranspiration of treated wastewater contained in a lagoon and sprayed at intervals on a forested area.

At Seneca College in King City, Ontario, campus effluent (wastewater) pumped into a treatment plant is subjected to activated sludge treatment resulting in nutrient consumption by microorganisms; excess sludge settles down and is later removed. The treated wastewater is pumped into a lagoon (2.5 ha) for secondary settling and further aeration treatment.

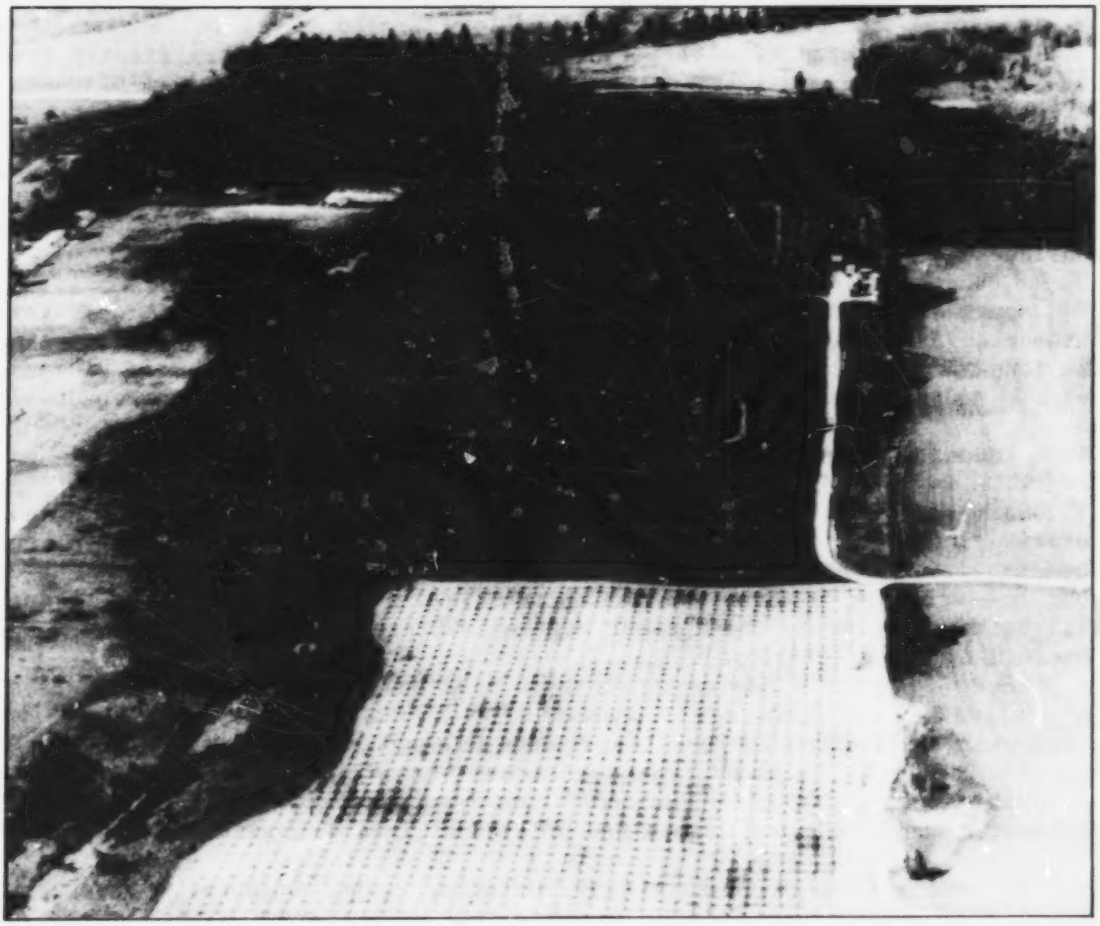
Site Preparation and Planting

At the request of Seneca College in King City, Ontario, the Ontario Tree Improvement and Forest Biomass Institute agreed to co-operate in afforesting the original effluent disposal area, previously maintained under a natural grass cover. The site was prepared adequately and weed competition was suppressed with herbicides. The site was then planted with one-year-old rooted cuttings of a number of poplar clones. In subsequent years, additional

areas were planted, and the total number of clones was increased up to a current 25 poplars, two willows and two alders.

The significant foliage development of poplar and the shape of the crown considerably enhanced the evapotranspiration of the planted stand. During a dry summer, the daily evapotranspiration deficit may now be as high as 5 mm.

(P. Jaciw and C.S. Papadopol)



At Seneca College, fast-growing hardwoods (light area, foreground) are sprayed with treated effluent held in a storage lagoon (dark oblong near top). The trees absorb moisture and nutrients and dissipate the effluent.

Foliar Analysis

In August of 1987, leaf samples were collected from a series of effluent-sprayed and control poplar clones of selections Leuce and Aigeiros. The leaves were compared as to size, total and specific weight and chemical components. Diameter increments were recorded weekly with the modified Ontario dendrometer tape. All comparisons demonstrated appreciable differences among treatments and tree types.

Foliar content was assessed to determine levels of major nutrients. Nitrogen, Phosphorus, Potassium, Calcium and Magnesium were evaluated in this preliminary study as a means of classifying poplar clones with respect to their ability to act as foliar nitrogen sinks in effluent-recycling areas (Table 12).

Analysis of variance of foliar nutrient content of major nutrients of some clones, both control and effluent-sprayed, has shown a remarkable differentiation by means of the F-test. The foliar Nitrogen and Phosphorus content were considerably affected by the spray (F-values 26.6 and 23.3 respectively).

The multiple-range analysis for Nitrogen by clone has shown that the clones respond in a different way to effluent irrigation. In general, average foliar Nitrogen content increased from 2.07% in controls to 2.41% in the effluent-sprayed foliage. However, not all clones reacted in a similar manner. Thus, no increase in Nitrogen content was recorded in the Leuce clone GA-88, while the Aigeiros clone DN-19 was characterized by an increase of about 25% in foliar Nitrogen content.

An interesting change in nutrient balance appears to take place as a result of effluent irrigation. In general, as the foliar Nitrogen increases, the Phosphorus concentration decreases. Although these results are statistically significant, they should be considered preliminary, and the experiment should be repeated.

A special case is represented by the clone GA-88: neither the foliar concentration of nutrients nor the ratios between them changed as a result of effluent irrigation. In this respect GA-88 is genetically more conservative, showing a low reaction to supplemental nutrient input.

A preliminary conclusion of this experiment would be a recommendation to choose clone DN-9 and to reject GA-88 when establishing effluent-recycling fields where Nitrogen depletion is required.

TABLE 12 Main element concentration of four poplar clones (% mg/gr).

Clone	Control			Effluent			Effluent-Control		
	N	P	K	N	P	K	N	P	K
GA-88	2.41	2.02	12.94	2.25	3.12	15.04	-.16	+1.10	+2.10
DN-19	2.11	4.71	20.80	2.52	2.15	18.79	+.41	-2.56	-2.01
DN-16	1.82	4.91	17.02	2.38	2.51	15.53	+.56	-2.40	-1.49
DN-9	1.96	5.02	18.27	2.48	2.13	17.18	+.52	-2.89	-1.09

(P. Papadopol and P. Jaciw)

DE.BAS: A Data Collection Program for the Microflex

With the advent of the electronic data collector, which allows data collection in the field, the need for a program flexible enough to capture a variety of data was evident. Several specific programs were available, but each program required modification before it was usable. The lack of such software for the CP/M Microflex data collector led to the development of program DE.BAS which was written in GW-BASIC on an IBM AT compatible. Program DE.BAS allows the user to collect data without having to modify the program for each data collection. By setting up a file which describes the data (header file), program DE.BAS can read the specific header and prompt the user for the data they wish to collect.

The program also checks each entry to ensure that the value is within limits specified in the header. If the header is "well-ordered", that is, it has, for example, four blocks with 20 treatments per block and 100 trees per treatment, then a data file can be created beforehand. The advantage of this is that the user does not have to enter any identification while collecting data in the field. This means, for the example given, the user would be told they are at a specific tree—Block 3, Treatment 4, Tree 50, say. The user then has the option to either measure this tree, or move to another tree.

The final data file is in ASCII format with a fixed record length. The data file is "lined-up" in columns with the decimals aligned. Therefore, once the data is transferred, to an IBM PC, for example, it can be sent to a printer for quick examination, editing and analysis.

The program is being used extensively at the Northern Forest Research Unit in Thunder Bay and for collecting plantation response data from a series of reference plantations established under the auspices of the Northern Forest Development Group. A report is being prepared on the use of program DE.BAS for publication later in 1988.

(R.R. Forslund)

Monitoring Seasonal Diameter Increments for Evaluating the Performance of Fast-Growing Species

Plantation establishment and intensive stand management benefit from the short-term evaluation of tree performance in relation to site and cultural treatments. Dendrometers can be used effectively for this purpose as they provide current diameter growth information for individual trees, clones and stands.

Monitoring growth with dendrometer tapes permits correlation of current annual increments (CAI) with the mean annual increments (MAI) for the preceding years. The method provides realistic criteria for determining optimum tree performance in relation to cultivars, rotation, spacing and site.

Dendrometer measurements and treatment evaluation were carried out in a number of trials. Red oak planted in mono- and polycultures showed a clear need for protection and corrective pruning, particularly during the initial phase after planting. Positive allelopathic effects were observed between oak and hybrid aspen, between black locust and American basswood, and particularly between European alder and white ash. Select clones of poplar hybrids served an excellent nurse crop function to a whole series of tolerant and semi-tolerant hardwoods including black walnut, as well as to conifer species such as white pine and white spruce grown in dual-crop mixedwood plantations.

This approach to growing hardwoods and conifers in mixtures is based on the principles of species association and succession. The technique consists of the initial establishment of suitable pioneer species for site preconditioning, followed by the introduction of semi-climax or climax species. Such quasi-natural stand development is particularly effective on impoverished, non-forested sites, which greatly benefit from substantial accrual of humus and nutrients returned annually by the fast-growing pioneer species in their litter and through nitrification. Establishment of balanced associations is strongly favoured by the differential requirements and habits of the intolerant, semi-tolerant and tolerant species, leading to appreciably improved site utilization and valuable symbiotic relationships among trees. Mixed forest communities exert a profound effect on stand sanitation, preventing epidemics or infestations by insects and diseases. They contribute to a richer, more varied ecology and provide a variety of valuable industrial products while offering highly pleasing aesthetic and recreational opportunities.

(P. Jaciw)

SITE RESEARCH

Regional Ecology

The objective of this program is to provide the forest and land manager with a broad framework which would be useful in the transfer of ecological information over large distances. This basic framework is provided by Site Regions. These regions are recognized on the basis of specific local relationships between stand dynamics (e.g. stand succession, species competition, growth) and positions in the landform: they deal thus with ecosystems. Differences in these ecological relationships among regions are due to the effect of macroclimate, mainly temperature and humidity.

Site Region boundaries suggest the limits within which specific silvicultural prescriptions for similar ecosystems apply, but beyond which considerable adjustments may be required. Site Regions provide a province-wide ecological framework for forest and land inventories, land-use and park planning, seed zones and other silvicultural guidelines, and probably also for wildlife management.

(D. Burger)

Site Regions of Ontario

Two projects are in progress. One deals with a summary of concepts and methodology used in the recognition, description and mapping of Site Regions. It is meant to clarify to the users of these regions their values and limitations. Furthermore it should serve as a reference for research in the recognition of Site Regions in other areas, such as eastern North America and northeast China (see below). Information is also being compiled for another project which summarizes descriptions of the Site Regions centred on the relationships between vegetation and landform-positions, with additional information on climate and other regional features.

(D. Burger)

Ecoclimatic Regions of Canada

The concept of Site Region has been adapted and used in the now completed national project on Ecoclimatic Regions of Canada. A manuscript and map based on contributions from federal and provincial researchers across Canada are being edited for final publication by Environment Canada.

(D. Burger)

Site Regions of Northeastern North America

The exchange of scientific and technical information between the United States and Canada would benefit from a regional ecological framework covering both countries. To this end, a project was started a few years ago to extend the concept of Site Region southward from Ontario. A great deal of scattered information on tree species–landform relationships is available in numerous publications. A literature search, extraction of pertinent information and fitting of data into the site region model are in progress.

(D. Burger)

Regional Forest Ecology, Northeast China

This project deals with a general comparison of forest ecological conditions in northeast China and Ontario. A series of maps of physiography, vegetation, climate, and bedrock geology was drawn and a manuscript was written in cooperation with Mr. Zhao Shidong of the Institute of Forestry and Soil Science, Academia Sinica, Shenyang, Liaoning, P.R.C., and submitted to a journal for publication.

(D. Burger)

Inorganic Laboratory

The inorganic laboratory conducted chemical nutrient analyses of soil and foliar samples for several regional and district staff, in addition to assisting the research scientists.

During 1987 the laboratory processed approximately 8 000 samples and completed over 11 000 determinations such as: pH (1:1 soil/water suspension); texture (Bouyouces); cation exchange capacity (leached with ammonium acetate and ethanol, distilled into boric acid, titrated with hydrochloric acid); organic matter (Walkely-Black method using potassium dichromate and sulphuric acid); nitrogen (Kjeldahl method, digestion with sulphuric acid,

distillation into boric acid, titration with hydrochloric acid); available calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) in soils (determined on atomic absorption spectrophotometer), extractable phosphorus (P) in soil (Bray and Kurtz method of extraction, concentration determined by U.V. spectrophotometry); total calcium (Ca), magnesium (Mg), potassium (K), iron (Fe), copper (Cu), zinc (Z), aluminum (Al) and manganese (Mn) (in foliar and water samples, concentration determined by atomic absorption spectrophotometry).

(L.J. Spence and L. Packer)

In the biochemical laboratory, chemical technician Ernie Chen is using a spectrophotometer to measure sugars and anthocyanins extracted from jack pine tissue.

Productivity, Nutrient Cycling and Acid Precipitation Effects in Spruce Forest Ecosystems

Long-term ecosystem studies are providing information enabling prediction of productivity effects of full or whole-tree harvesting on different landtypes, constraints of nutrient budgets on harvesting and rotation ages, and the role of acid precipitation on nutrient cycling, growth and nutrition, and on stand health and stability.

Three forest soil conditions are under detailed comparative study: i) long-residence spruce, spruce–fir and spruce hemlock; ii) long-residence hardwood; iii) long-residence hardwood converted to spruce plantation.

Long-term static sampling of soil conditions measures changes taking place as a consequence of conversion from hardwoods to conifers. Dynamic sampling in the long-residence spruce stand measures the pattern of seasonal flux (nutrient transfers) and the incrementally slow changes that may be taking place in this none-too-well-buffered spruce forest soil, a typical orthic ferro-humic podzol.

Drought associated with periodic occurrences of hot dry weather has doubtless been a prime factor in restructuring and stressing natural coniferous stands. Our extensive increment core data as well as stand structural changes indicate such critical periods did occur in the 1960s.

However, in the life of a stand on most landtypes, such events may be expected to have occurred a number of times. Furthermore, during the long evolutionary life of a species, even greater disruptions will have occurred many times, through all of which the species has still survived to come down to present times.

The problem of sudden species decline may occur so that the frequency of the species markedly drops (diminished range or lowered site occupancy, or both). Many individuals in a given area may lose vigour, and crown deterioration which leads to death sets in. Examples of real decline are elms dying from Dutch elm disease, an introduced disease; the still only partially explained yellow birch dieback or deterioration of the 1940s, '50s and '60s; (commercial birch essentially disappeared before this problem was really solved); the widespread and permanent reduction in stands of eastern larch or tamarack in the 1930s and '40s from larch sawfly depredation; (some strains of this insect were introduced); the current decline of spruce in the Appalachian Mountains; and the strong indications of decline in sugar maple in parts of its range close to industrial centres.

Spruce forests in North America have occasionally declined from attacks of the spruce beetle (*Dendroctonus rufipennis*), a principal insect in the extensive eastern spruce forests in early logging days. It remains important in the still-extensive spruce stands in western North American forests. The recurring spruce budworm, however, never caused spruce forests to decline in

the east. The forests have always rejuvenated even in the presence of budworm.

There is a general ecological principal which states that cyclic insect devastation of trees never results in the ultimate decimation of the host tree species. It is not a good strategy for insects ultimately to destroy their host species, since this also results in self-extinction. This does not happen in nature where species have evolved together over long periods of time. It happens only when introduced pest species are brought in contact with host species not selected for survival against the pest. This principal operates for all North American tree species and their North American pests.

If decline is recognizable, affecting one or more tree species and resulting in permanent change; and if it may not reasonably be accounted for by major climatic effects alone; other effects such as acid rain may be contributing. The effects of acid rain on forest ecosystems are less direct than those on lakes and forest waters. Forest soils are usually much more buffered than are waters, and some much more so than others. Forest soils in central and northern Ontario are for the most part moderately acidic, and are therefore not nearly as well buffered against acid rain as are the calcareous soils of the south. Partitioning the effects in such a complex is difficult. Stand history, buffering capacity of the soil, and variation in species response are all immediately involved.

Two long-term studies are contributing to the understanding of this problem. The first consists of the detailed nutrient-cycling and growth and nutrition studies in natural spruce forest ecosystems mentioned previously. The second is from a series of *Piceta*, experimental spruce plantations, which we have established in seven districts representing southeastern, southwestern, Algonquin, northeastern, north central and northwestern Ontario. There are a large number of spruce species and genotypes planted in these *Piceta*. The temperate climates of the more southern *Piceta* permit a greater array of types than the more severe climates of those in the boreal forest.

The *Piceta*, already extremely useful as breeding arboreta, are expected to yield many types of useful information, particularly genotype x environment interaction, of increasing importance in tree improvement work. In addition, since many genotypes are replicated across a gradient of latitude (day length and temperature) as well as a parallel, but not identical, range from negligible to moderate acid rain conditions, they can be used as long-term monitors of total air pollution and acid rain dysfunction if it appears.

Some of the classic long-term studies of nutrient depletion and amendment have been done in New York State, essentially on farmed-out, abandoned agricultural land which originally should have remained in forest. The cleared lands on which our *Piceta* were established in southern Ontario were never farmed-out. As for the rest, all were established on clearcut or partially-cut forest land. All are growing on essentially natural forest soils. Aberrations occurring on these sites will not be due to unaccounted-for causes relating to excessive original agricultural practices, which would require further analytical partitioning.

(A.G. Gordon)

PAPERS AND POSTERS PRESENTED

ANDERSON, H.W., D.C.F. FAYLE and D. MacIVER. Stress in forest trees. International Society of Arboriculture.

ANDERSON, H.W. Sugar maple–its growth, quality and regeneration. Forest Decline Workshop, University of Toronto.

COLOMBO, S.J. Review of the findings of the Thunder Bay container stock loss investigation. Northern Region Growers Association, Timmins, 8 July 1987.

COLOMBO, S.J. Extended Greenhouse Culture and root hardiness. Container Seedling Production Update: 1987. Maritime Forest Ranger School, Fredericton, New Brunswick, 14-15 July 1987.

COLOMBO, S.J. Predormancy in black spruce. First Ontario Tree Seedling Researcher's Meeting, Kirkland Lake, 17-18 Sept. 1987.

COLOMBO, S.J. and G.D. RACEY. Overwinter storage of nursery stock. Taking stock: The role of nursery practices in forest renewal. Ontario Forest Research Committee Symposium, Kirkland Lake, 14-17 Sept. 1987.

GLERUM, C. Planting stock quality evaluation. Taking stock: The role of nursery practices in forest renewal. Ontario Forest Research Committee Symposium, Kirkland Lake, 14-17 Sept. 1987.

GORDON, A.G. Gave a lecture on spruce-fir forest stand dynamics and the effect of the budworm–implications for management. Forest Management and Roads Committee, Ontario Forest Industries Association, Toronto, 29 Jan. 1987.

HO, R.H. Cone induction research at OTIFBI. Breeding Hall Working Group Meeting, Kemptville, 3 March 1987.

HO, R.H. Progress report on cone induction. Breeding Hall and Vegetative Propagation Working Group, Swastika, 15 Oct. 1987.

HUTCHISON, R.E. Cool and cold storage/field storage and handling. OMNR Northern Region–Stock Handling & Storage Seminar, Timmins, 5 Oct. 1987.

KOPPENAAL, R.S. and S.J. COLOMBO. Increasing heat and frost tolerance in black spruce seedlings by bud initiation. Taking Stock: The role of nursery practices in forest renewal. Ontario Forest Research Committee Symposium, Kirkland Lake, 15-17 Sept. 1987. (Poster)

KOPPENAAL, R.S. and S.J. COLOMBO. Survival and water relations of drought-conditioned spruce and pine container stock. First Ontario Tree Seedling Researchers Meeting, Kirkland Lake, 17-18 Sept. 1987.

McCLAIN, K.M. Deciding when and what to plant? Be careful! Taking stock: The role of nursery practices in forest renewal. Ontario Forest Research Committee Symposium, Kirkland Lake, 15-17 Sept. 1987. (Poster)

McCLAIN, K.M. Aspects of testing seedlings for vitality during over-winter storage (in response to Stock Loss Report-NCR). Northern Forest Development Group, Private growers.

McCLAIN, K.M. Northern Forest Development Group: Presentation to development foresters and technicians on:

1) Use of dry weight percent in monitoring seedling physiology through dormancy and frost hardiness development.
2) Aspects of assessing performance of over-winter frozen-stored container seedlings.
3) Summary reports as scientific authority for Client Planting Trials conducted in the Northern Region.

McCLAIN, K.M. Operational planting and biological considerations. North Central Region, Forest Information Transfer Session.

McCLAIN, K.M. Plant water relations and importance to seedling establishment. North Central Region, Physiology short course.

McCLAIN, K.M. Procedures to monitor growth of containerized seedlings. North Central Region, Private growers.

McCLAIN, K.M. Research in the north: past, present and future. Canadian Institute of Forestry, Northwestern Ontario Section.

McCLAIN, K.M. Response of conditioned jack pine and Douglas-fir container seedlings during drought stress. Ancillary research meeting to COFRC Symposium, Kirkland Lake, 18 Sept. 1987.

ODLUM, K.D. and S.J. COLOMBO. The effect of bud initiation regime on the timing and duration of second-year shoot elongation. First Ontario Tree Seedling Researchers Meeting, Kirkland Lake, 17-18 Sept. 1987.

ODLUM, K.D. and S.J. COLOMBO. The effect of greenhouse temperatures on bud initiation. Taking Stock: The role of nursery practices in forest renewal. Ontario Forest Research Committee Symposium, Kirkland Lake, 15-17 Sept. 1987. (Poster)

PATERSON, J. Experimental research results. Sir Sandford Fleming College. Half-day lecture to students on nursery course.

PATERSON, J. Planting procedures which affect plantation establishment. Brinkman Contracting (B.C. private planting contractors). Half-day lecture at Ganaraska Forest Station to planting foremen.

PATERSON, J. Red pine needle length in relation to field performance. Northeastern Area Nurserymen's Conference, Hayward, Wisconsin.

RACEY, G.D., R. SKIDMORE and B. PELTIER. The Issues Surrounding Stock Variability. Issue paper provided as follow-up to Stock Production Development Activity Seminar, Timmins, 1-4 Dec. 1987.

UNIVERSITY INVOLVEMENTS

ANDERSON, H.W.

Adjunct Professor of Silviculture, University of Toronto, Faculty of Forestry.

Member of undergraduate currriculum review committee, University of Toronto, Faculty of Forestry.

Lectured to undergraduates in Forest Products and Silviculture, University of Toronto, Faculty of Forestry.

Adjunct Professor of Agroforestry, University of Guelph.

Committee member for PhD graduate student, University of Guelph.

BUCHERT, G.

Serves on PhD advisory committees for two students at the University of Toronto.

GLERUM, C.

Serves on supervisory committee for two MScF candidates and one PhD candidate, University of Toronto, Faculty of Forestry. One MScF candidate successfully defended his thesis and graduated in November.

Gave a two-hour lecture on planting stock quality to third-year students in October. University of Toronto, Faculty of Forestry.

GORDON, A. G.

Gave a seminar on Systematics and biogeography of *Picea*. Interdepartmental Systematics Group, University of Guelph, 23 Mar. 1987.

Gave a lecture on Stand dynamics of the spruce-fir forest and the budworm—implications for management. Forestry Seminar Series, Lakehead University, Thunder Bay, 25 Nov. 1987.

Associate Member of the Graduate Faculty (School of Graduate Studies). University of Toronto, Faculty of Forestry.

HO, R.H.

Lectured on biotechnology in forest genetics and tree breeding. University of Toronto, Faculty of Forestry, 19 Mar. 1987.

McCLAIN, K.M.

Lectured on seedling physiology and growth response after planting (degree students). Lakehead University.

Lectured on the importance of seedling quality for successful reforestation (technical students). Lakehead University.

Special lecture series: Research at the Northern Forest Research Unit: black spruce. Lakehead University.

Special lecture series: Seedling Physiology: Can cultural practices affect plantation performance? Laval University, Faculty of Forestry.

Round table group discussion leader on plant water relations determined from pressure-volume data. Laval University, Faculty of Forestry.

Special Lecture Series: graduate students. Seedling physiology and importance of cultural practice to seedling field performance. University of Toronto, Faculty of Forestry.

Member of two MScF committees and one fourth-year thesis committee, supervisor of one fourth-year thesis committee. University of Toronto, Faculty of Forestry.

PAPADOPOL, C.S.

Gave a seminar on ecological significance of soil permeability for water balance and nutrition studies in nurseries and stands. University of Toronto, Faculty of Forestry, March 1987.

Member of advisory committee for one MS candidate, University of Toronto.

SKRATES, D.A.

Presented two noon-hour lectures on seed production and provenance variation at the University of Toronto, Faculty of Forestry.

Working in cooperation with Botany Department, Lakehead University in the provision of sorted seed for a biochemistry project.

COMMITTEES

ANDERSON, H.W.

Maple Complex Woodlot Committee (OMNR).

Maple Syrup Research Committee (Ontario Ministry of Agriculture and Food).

ANSI—Areas of Natural or Scientific Interest (OMNR).

Provincial Silviculture Guide Committee (OMNR). Principal author of "Silvicultural Guide to the Tolerant Hardwood Working Groups".

Ontario Forest Research Committee, Regeneration Subcommittee (OMNR).

Algonquin Regional Growth Study (OMNR).

Undergraduate Curriculum Review (University of Toronto).

BUCHERT, G.

Abitibi-Price Working Group on Jack Pine.

Ontario Forest Research subcommittee of Ontario Forestry Council.

Audit Team for audit of Eastern Region Fast Growing Forests Group.

OMNR Working Group on Clonal Forestry/Rooted Cuttings.

OMNR Scientific Steering Committee of Eastern Region Fast Growing Forests Group.

Resistance to Pests Working Group of Ontario Forestry Council.

OMNR Design Committee for OTIFBI forest research facility at Sault Ste. Marie.

Observer, FAO, North American Forestry Commission.

McCLAIN, K.M.

Scientific member of Stock Production Development Activity Committee. Met frequently to deal with issues arising from Symposium: Fitness for Purpose. Principal objectives were to oversee the award of $250,000 per year (for five years) by issuing Requests for Proposals. Sponsored research is encouraging the resolution of problems and increasing our understanding of factors in relation to stock production, planting, physiology, field performance.

Appointed Chairman of the Technical Advisory Committee of the Northwestern Ontario Forest Technology Development Unit. This committee's mandate is to review all development projects for technical merit, revelance and feasibility and to review long-term program strategies.

PAPADOPOL, C.S.

Steering committee for a grant related to irrigation of wastewater given by the Ministry of the Environment to Guelph University.

OTHER ACTIVITIES

ANDERSON, H.W.

Conducted marking courses and hardwood silviculture seminars at Bracebridge and Pembroke, Algonquin Region.

Scientific authority for COFRDA Project 33012, Post harvesting silvicultural techniques to enhance the white pine and red oak components in shallow site forests in Central Ontario.

GLERUM, C.

Led a scientific team in early May (part of an administrative investigation team) to investigate container stock losses of seven million in the Thunder Bay area.

Organized and presented two two-day tree physiology courses for senior nursery staff:

25-26 Feb. in Lindsay, Ontario with Prof. E.B. Dumbroff, Waterloo University and S.J. Colombo.

3-4 Nov. in Thunder Bay, Ontario with Prof. E.B. Dumbroff, Waterloo University and Dr. K.M. McClain.

Organized the first Ontario tree seedling researchers meeting at Kirkland Lake, Ontario, 17-18 Sept. The purpose was to improve communications among researchers dealing with all aspects of container seedling research by providing an opportunity to meet formally and exchange ideas.

Scientific Authority on three COFRDA projects.

HO, R.H.

Referee for an USDA Research Grant Proposal, April, 1987.
Referee for a research paper for Can. J. Bot., July, 1987.
Referee for a research paper for Can. J. For. Res., October, 1987.
Referee for a research paper for Plant Cell, Tissue and Organ Culture, November, 1987.

McCLAIN, K.M.

Participated as a member of the scientific team investigating container seedling losses at the Thunder Bay Forest Station and the facilities of five private growers in the vicinity of Thunder Bay (report entitled: "Report on the 1987 Losses of Container Stock in the Thunder Bay Area").

A joint proposal was made and approved by the Executive Committee of the Northwestern Ontario Forest Technology Development Unit to place the library holdings of the Northern Forest Research Unit onto computer. The objective of this joint venture is to increase accessibility of silviculture research information to scientists and program foresters of the NWOFTDU.

Scientific Authority on five projects:

1. The influence of red: far-red light quality ratios and their interaction with elevated CO_2 levels on containerized tree seedling growth and survival. Investigators: Dr. John Hoddinott and Mr. E.J. Daly, Department of Botany, University of Alberta. Sponsor: Northern Forest Development Group, Northern Region.

2. Establishment and early growth of black spruce in relation to seedling physiology at time of outplanting. Investigator: Prof. R.J. Day, Lakehead University. Sponsor: COFRDA

3. Jack pine and black spruce seedlot improvement for single seed container sowing, Physiology and Biochemical Investigations. Investigator: Prof. L. Malek, Lakehead University. Sponsor: COFRDA

4. Project (co-authority): Effects of photoperiod and plant growth regulators upon vigour of coniferous seedlings. Investigators: Prof. D.P. Lavender, Dr. T. Kannangara and Mrs. L. Charleson, Forest Science Department, University of British Columbia. Sponsor: Northern Forest Development Group, Northern Region, OMNR.

5. Project: Development project: Client Planting Trials. Investigator and Sponsor: Northern Forest Development Group, Timmins, Ontario.

ODLUM, K.D.
Member of the committee representing OTIFBI's interests in the design and planning of the new headquarters to be constructed at Sault Ste. Marie.

PAPADOPOL, C.S.
Reviewed a research proposal for Natural Sciences and Engineering Research Council of Canada.

Reviewed a research paper prepared for the journal Soil and Water on the irrigation of short-rotation intensive cultures of hybrid poplar.

Gave technical guidance for the implementation of automated weather data collection for the irrigation activity at St. Williams and Midhurst nurseries.

RACEY, G.D.
Conducted a statistics & container stock sampling workshop for OMNR Northern Region staff, private container growers and forest industry personnel. Kirkland Lake, Ontario. 17-19 Feb. 1987.

SKEATES, D.A.
Presented at National Tree Seed Testing Workshop held at Petawawa National Forestry Centre.

INTERNATIONAL DEVELOPMENT

SKEATES, D.A.
Arranged southern Ontario tours for a group of Thai scientists as part of a training program in Canada. Participants are on doctoral programs at the University of British Columbia.

Arranged and participated in meeting of Forest Resources with visitors from the National Economic and Social Development Board of the Royal Thai Government.

Participated in CIDA briefing session for Canadians going to Thailand for development projects.

Presented seminars on Thailand and Forestry in Thailand at Maple and at Great Lakes Forestry Centre in Sault Ste. Marie.

VISITORS TO OTIFBI

Jim Coles (Ontario Tree Improvement Council).
Dr. Paul Pukacki, Kornik, Poland.
V. Steenackers, Belgium.

PUBLICATIONS

------- Hybrid Poplar Trial Catalogue, 1955-1984. OMNR/OTIFBI. 139 p.

BURGER, D. Forest ecosystem and forest management: physiography as an integral part of forest ecosystems. In: The Temperate Forest Ecosystem, ITE symposium no. 20. Y. Hanxi, Wang Zhan, J.N.R. Jeffers and P.A. Ward (Eds.). Proc. of international symposium on temperate forest ecosystem management and environmental protection, Changbai Mountain Research Station, Academia Sinica, Antu, Jilin Province, People's Republic of China, 5-11 July 1986. 6 p.

COLOMBO, S.J. Changes in osmotic potential, cell elasticity, and turgor relationships of second-year black spruce container seed-

lings. Can. J. For. Res. 17(5): 365-369.

COLOMBO, S.J. Nursery Notes—lost and found (an annotated bibliography). OMNR. 34 p.

COLOMBO, S.J. and D.F. HICKIE. A one-day test for determining frost hardiness using the electrical conductivity technique. OMNR Forest Research Note No. 45. 4 p.

COLOMBO, S.J. and K.D. ODLUM. Efficacy of six antitranspirants on black spruce container seedlings. New Forests 3: 239-244.

COLOMBO, S.J., K.D. ODLUM and C. GLERUM. Measuring and improving the physiological quality of planting stock. In: Proc. Stock Production Activity Seminar, Timmins, 1-4 Dec. 1986.

GLERUM, C., J.M. PATERSON and G.D. RACEY. The development of planting stock standards to ensure plantation establishment. In: Fitness for Purpose. Proceedings of stock production development activity seminar stock standards and early plantation performance. Dec. 1986, Timmins, Ontario. 9 p.

HO, R.H. Embryo culture. In: Cell and Tissue Culture in Forestry. J.M Bonga and D.J. Durzan (Eds.). Maritimes Nijhoff Publ., Dordrecht. Vol. II: 137-167.

IRVING, D.E., K.J. GASHOKA and D.A. SKEATES. Small-scale seed extractory. OMNR Forest Research Note No. 43. 4 p.

KIM, Y.T. and C. GLERUM. Automated ion-exchange column system for biological sample fractionation. Anal. Chem. 59: 687-688.

KIM, Y.T., C. GLERUM, J. STODDART, and S.J. COLOMBO. Effect of fertilization on free amino acid concentrations in black spruce and jack pine containerized seedlings. Can. J. For. Res. 17(1): 27-30.

ODLUM, K.D. and S.J. COLOMBO. The effect of three film-forming antitranspirants on moisture stress of outplanted black spruce seedlings. Tree Planters' Notes 38(4): 23-26.

ODLUM, K.D. and S.J. COLOMBO. The effect of night temperatures on bud initiation in black spruce seedlings. In: Proc. Stock Production Activity Seminar, Timmins, 1-4 Dec. 1986.

PAPADOPOL, C.S. Operational Model for Water Requirements of Energy Cultures. Forest Energy Newsl. No. 8, 1987, p. 10-11.

PAPADOPOL, C.S. and J.D. NOLAN. Environmentally acceptable disposal of wastes from vegetable processing industries. In: Food Processing Waste Conf., 1-2 Sept. 1987, Georgia Inst. of Tech., Atlanta, Georgia, p. 152-161.

PAPADOPOL, C.S. and L. ZSUFFA. A simple model of growth and yield for irrigated and rainfed poplar minirotations for fuel. In: Fuelwood Production Strategies (L. Sennerby-Forse and C.P. Mitchell, Eds.). Proc. IUFRO XVIII World Congress 1986, 9 Sept. 1986, Ljubljana, Yugoslavia. Swed. Univ. of Agricultural Sci., Uppsala, 1987, p. 59-72.

PATERSON, J. Jack pine planting demonstration area, Garibaldi Township, Gogama District: first year results. OMNR/OTIFBI File Report. 35 p. + appendices.

RACEY, G.D. Undercutting and root wrenching in Ontario: Where Do We

Go From Here? In: Proc. Nurserymen's Meeting, Dryden Tree Nursery, 16-18 June 1987. pp. 18-25.

RACEY, G.D. and R.E. HUTCHISON. Tamarack and European larch can be overwinter-stored. For. Chron. 63: 179-181.

RACEY, G.D. and G.R. SANGUINS. An evaluation of sprayable latex mulches in some forestry applications. OMNR Forest Research Report No. 115. 9 p.

STROEMPL, G. Growth and quality of red oak planted in a jack pine plantation. OMNR Forest Research Note No. 44. 4 p.

STROEMPL, G. Growth and quality of red oak planted in red pine plantation openings. OMNR Forest Research Report No. 117. 6 p.

STROEMPL, G. Hardwood silviculture—thinning coppice growth to produce biomass and timber. Silviculture 2(2): 20-22.

Research assistant Oldrich Hak is working on flower and cone induction in potted black spruce.

ONTARIO TREE IMPROVEMENT AND FOREST BIOMASS INSTITUTE

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P. Mueller - Secretary

Administrative Support Unit
D. Callaghan - Executive Officer
M. Johnstone
J. Kucopy

Technology Transfer
D. Bates - Technology Transfer Specialist
D. Gillmeister +
J. Robinson

Systems Support
F. Matejka **

Tree Improvement and Biomass Section
G. Buchert - Principal Scientist
S. Brenham - Secretary

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J. Rice +	T. Taylor	F. Mestyan +
M. Touzin +	D. Higgs +	M. Pratchett +
J. Winters +	H. Kuschnik +	
P. Jaciw	M. Weishar	
A. Herzan +	A. Gordon	
D. Weingartner (TB)	M. Famiglietti (SSM)	
R. Collier + (TB)	N. Jondreau (SSM)	
	N. Lussier (SSM)	
	N. Balakrishnan + (SSM)	
	N. Deschamps + (SSM)	
	S. Leoppky + (SSM)	
	R. Ho	
	Y. Raj *	
	M. Baird *	
	W. Gibbs +	
	O. Hak +	
	C. Papadopol	
	D. Skeates	
	K. Gashoka +	
	D. Irving	

Forest Ecology and Silviculture Section
D. Burger - Principal Scientist
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Site and Productivity Unit	Silviculture and Tree Biology Unit
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L. Spence	C. Chen
M. Ashworth +	D. Hickie *
M. Connors +	R. Hutchison (MH)
M. Curtis +	B. Biggar + "
J. Nightingale +	B. Cole + "
L. Packer +	T. Gauley + "
G. MacDonald (TB)	A. Miller + "
D. Morris * (TB)	G. Sanquins +"
S. Hills + (TB)	S. Watson + "
M. Rose + (TB)	Y. Kim
K. McClain (TB)	J. Paterson
T. Casella (TB)	J. Schuppli +
R. Forslund (TB)	L. Spence (Mrs.) +
L. Kapron + (TB)	S. Colombo
	A. Cummins +
	R. Koppenaal *
	P. Menes +
	K. Odlum *
	S. Spezzaferro +
	N. Vanhinsberg +
	G. Racey (MH)
	G. Stroempl
	P. Papadopol +

\+ Seasonal
* Long-term contract positions
** Systems Services, Toronto

M.M. McLean - seconded, Algonquin Region
W. Ohlmann - seconded, Bracebridge District

ORGANIZATION AND STAFFING

1987 Staff Changes

In April, Diana Callaghan, who had been seconded to MNR's Forest Resources Group Program Planning and Budget Section as an Acting Group Advisor, returned to OTIFBI as Executive Officer.

Nancy Knudsen moved from the Northern Forest Research Unit in Thunder Bay to the Northwestern Ontario Technology Development Unit.

Gail Robinson, Librarian for the Northern Forest Research Unit, left to accompany her husband who was transferred to Alberta.

Blake MacDonald began an educational leave in August to complete a PhD at the University of British Columbia, where he will be studying competition dynamics and tending of young plantations in the boreal mixedwood forest.

Karina Bates left her position as Purchasing and Accounts Clerk in September to begin a four-year program in Administrative Sciences at Trent University in Peterborough.

After eight years as the Biometrician at OTIFBI's Midhurst Research Unit Field Station, Gerry Racey accepted the position of Integrated Resource Management Specialist with the Northwestern Ontario Forest Technology Development Unit at Thunder Bay.

Larry Spence, Chemical Analyst, was seconded to the Occupational Health and Safety Section of the Human Resources Branch in Toronto in November.

Ken Bennett, Leader of the Arboreta Unit, retired in August.

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